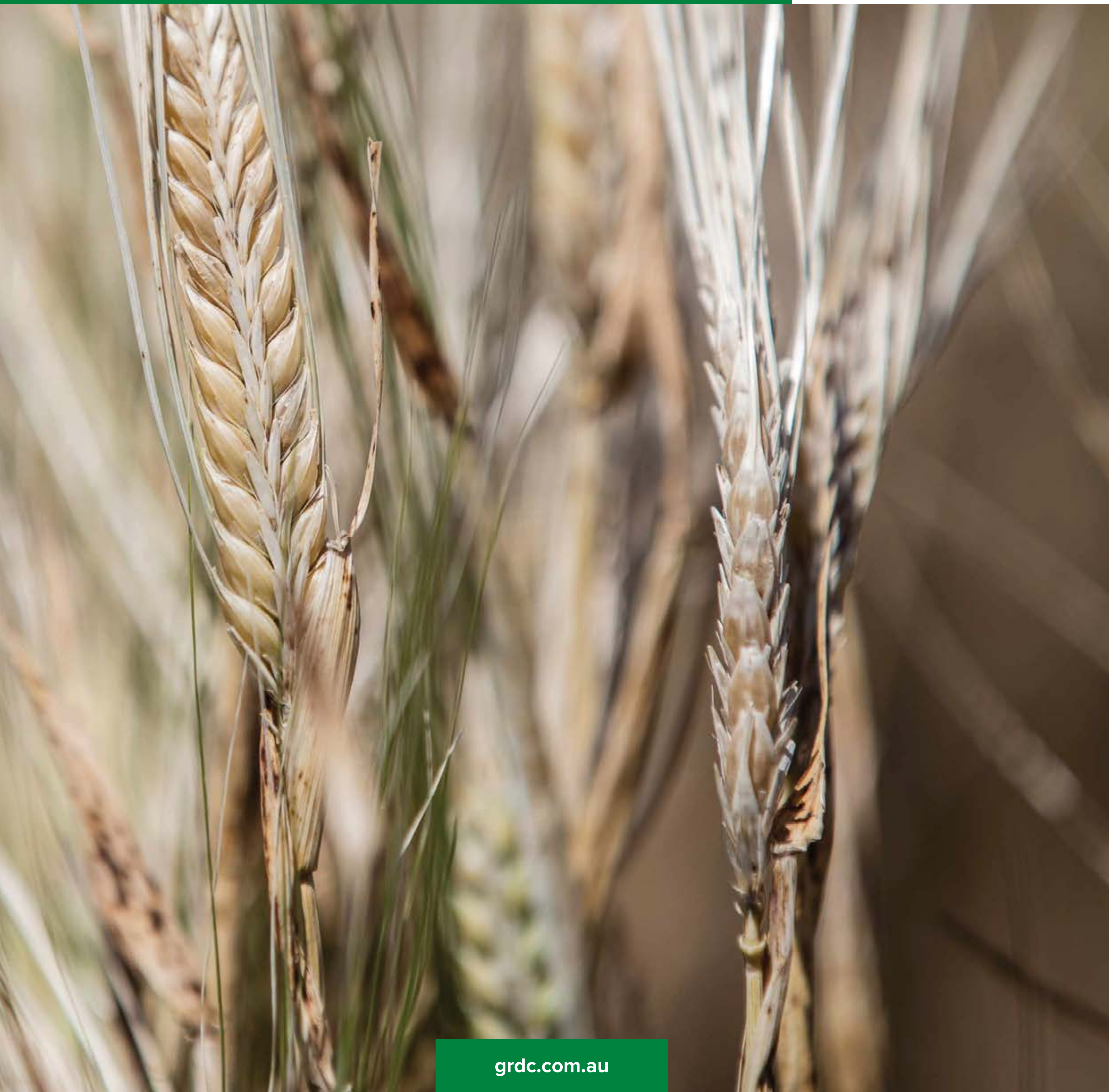
COONAMBLE NSW
WEDNESDAY 24 FEBRUARY 2021

GRAINS RESEARCH UPDATE
DRIVING PROFIT THROUGH RESEARCH

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION



GRDC 2021 Grains Research Update Welcome

If you are reading this, then chances are you are sitting in one of the GRDC's first face-to-face events since COVID-19 changed our lives.

Welcome.

We at the GRDC understand how challenging the past year has been for all Australians, but we also appreciate how well positioned agriculture has been to respond to and work through the restrictions that have come with this global pandemic.

Across many areas of Queensland and New South Wales, an improvement in seasonal conditions has also provided a much-needed reprieve for growers, advisers, agronomists, researchers and those associated with the grains industry.

With that positive change in circumstances comes a thirst for the latest information and advice from grains research and development – we trust that these GRDC Grains Research Updates will help guide your on-farm decisions this season and into the future.

While COVID-19 has forced temporary changes to our traditional Update locations and audience numbers, these events still offer the high quality, seasonally relevant research, development and extension information you have come to depend on. This year our Updates will also be live streamed to ensure the information is available to all who need it.

We would like to take this opportunity to thank our many research partners, who, like growers and advisers, have gone over and above to continue to work in situations constricted by COVID-19 regulations.

Challenging times reinforce the importance of rigorous, innovative research that delivers genuine gains on-farm. For more than a quarter of a century the GRDC has been driving grains research capability and capacity with the understanding that high quality, effective RD&E is vital to the continued viability of the industry.

Sharing the results from this research is a key role of the annual Updates, which are the premier event on the northern grains industry calendar and bring together some of Australia's leading grains research scientists and expert consultants.

To ensure this research answers the most pressing profitability and productivity questions from the paddock, it is critical the GRDC is engaged with and listening to growers, agronomists and advisers.

For the past five years we have been doing that from regional offices across the country. Through the northern region offices in Wagga Wagga and Toowoomba and a team of staff committed to connecting with industry, we are now more closely linked to industry than ever.

This year we have less people on the ground – as a result of COVID-19 restrictions – but more than ever we are available to listen and engage with you. So if you have concerns, questions or feedback please contact our team directly (details on the back of these proceedings) or email northern@grdc.com.au.

Regards,
Gillian Meppem
Senior Regional Manager – North

P PO Box 5367 Kingston, ACT 2604 Australia
T +61 2 6166 4500 **F** +61 2 6166 4599 **E** grdc@grdc.com.au

GRAINS RESEARCH & DEVELOPMENT CORPORATION ABN 55 611 223 291

grdc.com.au

GRDC Grains Research Update
COONAMBLE

Wednesday 24 February 2021

Showground Pavilion, Coonamble Showgrounds, 9565 Castlereagh Hwy, Coonamble

Registration: 8:30am for a 9am start, finish 2:50pm

AGENDA		
Time	**Topic**	**Speaker(s)**
9:00 AM	**GRDC welcome**	
9:10 AM	**Barley 2030 opportunities -** Vietnam, India and other markets	Mary Raynes (AEGIC)
9:45 AM	**Central Western NSW farming systems -** 5 years of findings at Trangie and Narrabri. What are the legacy impacts of rotation decisions?	Greg Brooke (NSW DPI)
10:20 AM	**Are there economic benefits in control of foliar fungal disease in canola crops in the low to medium rainfall zones of NSW?**	Maurie Street (GOA)
10:45 AM	**Morning tea**	
11:15 AM	**Cereal disease bingo!** Learnings from 2020 and planning for 2021. Is stripe rust the death knock for some varieties?	Steve Simpfendorfer (NSW DPI)
11:50 AM	**Impact of Ascochyta on chickpea when disease occurs at different growth stages**	Kevin Moore and Leigh Jenkins (NSW DPI)
12:20 PM	**Viral issues in pulse crops:** Why were fabas hit so hard in 2020? Causes & strategies for 2021	Joop van Leur (NSW DPI)
12:45 PM	**Lunch**	
1:35 PM	**Identification of crop-specific and varietal tolerance limits to acidity, salinity and sodicity.**	Yash Dang (UQ)
2:05 PM	**Amelioration for sodicity -** deep ripping and soil amendment research. Engineering challenges; yield responses to ripping, gypsum and OM placement in constrained soils	Chris Guppy (UNE)
2:35 PM	**Discussion -** Grower & adviser experience managing subsoil constraints	Discussion leader: Graeme Callaghan (Delta Agribusiness)
2:50 PM	**Close**	

Contents

Compiled by Independent Consultants Australia Network (ICAN) Pty Ltd.
PO Box 718, Hornsby NSW 1630
Ph: (02) 9482 4930, Fx: (02) 9482 4931, E-mail: northernupdates@icanrural.com.au
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Australian barley market opportunities towards 2030

Mary Raynes, Australian Export Grains Innovation Centre

Key words

barley, malting, feed, beer, market diversity, India, Vietnam, China, 2030

Take home messages

- It is important that Australian barley growers have access to a diversity of markets to reduce reliance on a single dominant buyer. The importance of this has been emphasised by the imposition of anti-dumping and countervailing duties on Australian barley exported to China
- Over the next decade Australia will need to maintain and grow its presence in important markets outside China. Users of barley in these markets including Vietnam, India, Japan, South Korea, China, Saudi Arabia, Middle Eastern nations, Iran, Thailand, Philippines, Indonesia, South America and the Sub Saharan Africa require information about Australian barley characteristics, functionality, and new varieties. The Australian industry will need to make breeding and classification decisions accounting for the needs of brewers and maltsters in these markets
- Development and presentation of information packages that reinforce the quality, value and fit of Australian feed barley to suit specific regions and animal types will support greater overseas use of Australian barley in monogastric and ruminant rations
- Towards 2030, China will remain the largest malting barley importer globally by a large margin and Australian barley quality already is well suited to Chinese requirements. There is substantial mutual benefit for the Chinese to remain informed of Australia's barley offering and for the Australian industry to continue to understand the evolving Chinese malting and brewing needs.

Background

The Australian Export Grains Innovation Centre (AEGIC) has examined a range of barley markets to provide insights to the Australian barley industry on their current and future barley needs. A summary of key findings is presented below. The full report can be download from the AEGIC website.

Key findings

Vietnam's growing beer consumption creates new opportunities

- Beer production will increase by a modest 2 to 3 per cent per annum to 2030. This will continue to create strong demand for imported malt and malting barley
- A forecast increase of Vietnam's malting capacity towards 2030, will see malting barley imports increase to about 330,000 mt, nearly double that required in 2019
- Malt imports will be needed to supplement domestic malt production as it adjusts to keep pace with rising demand
- Smaller opportunities may exist for feed barley, but this will be opportunistic and dependent on the price relativity against corn as the major feed ingredient.

Indian maltsters purchase more malting barley

- India is likely to continue to produce barley that is better suited to feed rather than malting use. India's downward trend in barley production is likely to continue, necessitating increased imports of malting barley

- The market for beer is expanding and it will capture an increasing market share over time as consumers move away from higher alcohol beverages like spirits to lower alcohol beverages like beer
- By 2030 India is likely to import 450,000 to 650,000 mt of malting barley with the Australian industry well positioned to supply a significant share of the imports.

Japan's demand for high quality food and feed barley will remain

- Demand for malt in Japan is unlikely to change substantially over the next decade
- Intense competition amongst Japanese breweries in the stagnant market is driving innovation in the sector to make more effective use of lower cost ingredients. This may provide opportunities for Australian and other cheaper origin malt to gain market share at the expense of higher priced Canadian alternatives
- Increasing health-consciousness is a robust and durable trend in Japan. Australia's export grains sector could position itself to gain advantage from this trend. An example is the growing health interest in barley beta-glucan for its health benefits
- Japan's requirement for a small amount of barley for specialised shōchū manufacture will continue to provide a high value opportunity
- Australia's historic position of holding a high market share in Japan's feed barley imports will need to be supported through high quality and competitive pricing against EU (European Union) and Black Sea competitors.

Malt is the main game in South Korea

- Towards 2030, South Korea provides more opportunity for Australian exports of malt than malting barley, but limited growth in Korean beer consumption constrains market prospects
- Opportunities for Australian feed barley in the South Korean feed market are likely to remain limited. South Korean feed manufacturers favour wheat over barley as a cereal feed.

China remains important to Australia's barley industry

- If tariff free access is restored, Australia will face increased pressure for a share of the Chinese malting market from other barley exporting countries, particularly Canada, Europe Argentina and potentially Ukraine and Russia in the feed market, as the volume of barley available for export from these countries grows
- China will remain the dominant market for malting barley towards 2030, with imports expected to remain at current levels within the range of 2 to 3 mmt per annum
- Over the next decade Chinese barley imports may increase by up to 2.1 mmt but the increase will be mostly feed barley, and strongly affected by government policies directed at other feed grains, particularly corn.

Saudi Arabia's demand for feed barley is declining but remains significant

- The Saudi Arabian government continues its endeavours to increase the use of domestically processed compound feed instead of imported raw barley. However, there remains a degree of resistance to this change, particularly amongst politically influential Bedouin livestock users who maintain the historical practice of direct feeding unprocessed barley to their livestock.
- If China continues to impose high tariffs on Australian barley, then Saudi Arabia is the only destination capable of utilising the volume displaced by Chinese barriers.

Other Middle East nations and Iran

- Other Middle East nations: including Kuwait, United Arab Emirates, Qatar, and Oman have historically used Australian barley for feeding livestock. Increasing demand across the Middle East and Iran will continue to be primarily serviced by Black Sea origins and Argentina. When Australian barley is cost competitive in the Saudi Arabian government tender, it is generally cost competitive into many of these markets.

Thailand's feed barley use is an ongoing opportunity

- Thailand's feed industry is an ongoing opportunity for Australian feed barley, when it is price competitive against their domestic crops like corn, or when there is a gap between domestic corn production and animal feed requirements.

Indonesia and Philippines present new feed options

- As incomes and populations increase in Indonesia and the Philippines, feed demand will grow strongly to service growing meat consumption. Currently, government policies in both countries protect domestic corn producers against cheaper corn imports. Imported barley may be price competitive against higher priced domestic corn and could be an effective feed ingredient if local feed millers become familiar with its use.

South America

- Malting barley use and malting capacity in South America will continue to grow with barley sourced mainly from within the region (principally Argentina). Supply disruptions caused by adverse production conditions (floods and droughts) coupled with volatile government policies may shift production incentives away from barley, and so may offer occasional opportunities for Australian exports.

Sub Saharan Africa

- Although South Africa is increasingly self-sufficient in barley, production volatility due to drought may provide occasional opportunities
- Smaller opportunities may arise in countries such as Ethiopia. Some Australian malt is already being supplied to this market.

Australia

- Towards 2030 Australia's barley production could increase to 13 mmt per annum from a current long term average of 9 mmt
- Domestic malting barley use is likely to remain relatively stable around 1.5mmt annually towards 2030
- Domestic feed consumption is likely to increase from 1.5mmt to 1.8mmt with increased use mostly in eastern Australia.

Contact details

Mary Raynes
AEGIC
3 Baron Hay Court, South Perth, WA 6151
Ph: 08 6168 9900
Email: mary.raynes@aegic.org.au

Soil moisture, nitrogen and disease legacy effects of different Central Western farming systems - 5 years of findings at Trangie

Greg Brooke, NSW DPI

Contact details

Greg Brooke
NSW DPI
Ph: 0437 140 577
Email: greg.brooke@dpi.nsw.gov.au

Notes

Was canola fungicide investment justified in low and medium rainfall environments in 2020?

Rohan Brill[1], Ben O'Brien[2] & Maurie Street[2]

[1] *Brill Ag*
[2] *Grain Orana Alliance*

Key words

canola, fungicide, Sclerotinia, upper canopy blackleg, Alternaria black spot, powdery mildew

GRDC codes

GOA2006-001RTX

Take home messages

- Return on investment was strong in only two of five trials, with both these trials being in the south and having higher levels of upper canopy blackleg (branch infection) as well as some Sclerotinia. Best return was from a single fungicide spray at 30% bloom stage
- Application at the recommended timings (30% and 50% bloom) were more likely to result in a yield benefit than an early application (10% bloom)
- Reduction in disease infection did not necessarily result in a positive grain yield response, similarly a positive grain yield response did not always increase profitability
- Overall, with modest yield responses in a high production year, money may be better invested in inputs with a more reliable return on investment.

Introduction

Application of fungicide to manage disease in canola, especially Sclerotinia and upper canopy blackleg (UCB) is a common practice in the higher rainfall, eastern and southern areas of the GRDC Northern Region, but there is little data on the cost-effectiveness in low and medium rainfall zones. In mid to late winter 2020 canola crops had high yield potential across much of the GRDC Northern Region. With forecasts for further rainfall for the spring period, many growers and advisors were considering the need for fungicide in areas where application is not common.

In response Grain Orana Alliance (GOA) and Brill Ag established five canola fungicide response trials through southern and central NSW to determine the response to fungicide in low and medium rainfall environments in a high yield potential season. The trials tested several fungicide products and their timing. The trials were assessed for the common diseases Sclerotinia and UCB as well as the less common diseases Alternaria black spot and powdery mildew that were also present at most sites. This paper outlines the key findings on the effectiveness of fungicide to control each disease as well as the grain yield response from fungicide control and the economics of their application.

Methodology

Trial sites were geographically spread to represent a range of climates and farming systems (Table 1). Trials were a randomised complete block design with four replicates for each treatment. Each trial was sprayed with a ute-mounted boom spray onto existing commercially grown and managed crops to ensure that the canopy remained intact, minimising open space for air to circulate which may have suppressed disease development. The sprayed plots were usually 40-50 m² in size with a smaller area of approximately 15-20 m² harvested with a small plot harvester when the crop was ripe (direct head) to minimise any potential influence from neighbouring treatments. All other crop husbandry prior to applications were completed by the grower.

Table 1. Site description for five canola fungicide response trials conducted in NSW, 2020.

Location	Region	Average annual rainfall	Average growing season rainfall	Variety
Ganmain	Eastern Riverina	475 mm	280 mm	HyTTec® Trophy
Kamarah	Northern Riverina	440 mm	220 mm	Pioneer® 44Y90 CL
Temora	South-west slopes	520 mm	310 mm	Pioneer® 45Y91 CL
Warren	Central-west plains	510 mm	210 mm	HyTTec® Trophy
Wellington	Central-west slopes	580 mm	300 mm	Victory® V75-03CL

Four products were used with multiple combinations of timings and rates (Table 2).

Table 2. Description of fungicide products used in five canola fungicide response trials conducted in NSW, 2020.

Trade Name	Active Ingredient 1	Group	Active Ingredient 2	Group
Aviator Xpro®	Prothioconazole	3	Bixafen	7
Miravis® Star**	Pydiflumetofen	7	Fludioxonil	12
Prosaro®	Prothioconazole	3	Tebuconazole	3
Veritas®	Tebuconazole	3	Azoxystrobin	11

***Miravis Star was applied under a research permit . It is currently under evaluation with APVMA.*

There were three application timings targeted at 10, 30 and 50% bloom (30 and 50% bloom only at Kamarah and Warren). The 30 and 50% timings are commonly suggested timings, with the 10% bloom timing added to reflect grower practice at those sites. Treatments at individual sites are shown in Tables 4-8 later in the paper. These spray timings are overlaid on daily rainfall in Figure 1. After good rains in early to mid-August at all sites, rainfall during the late winter/early spring period was generally below average.

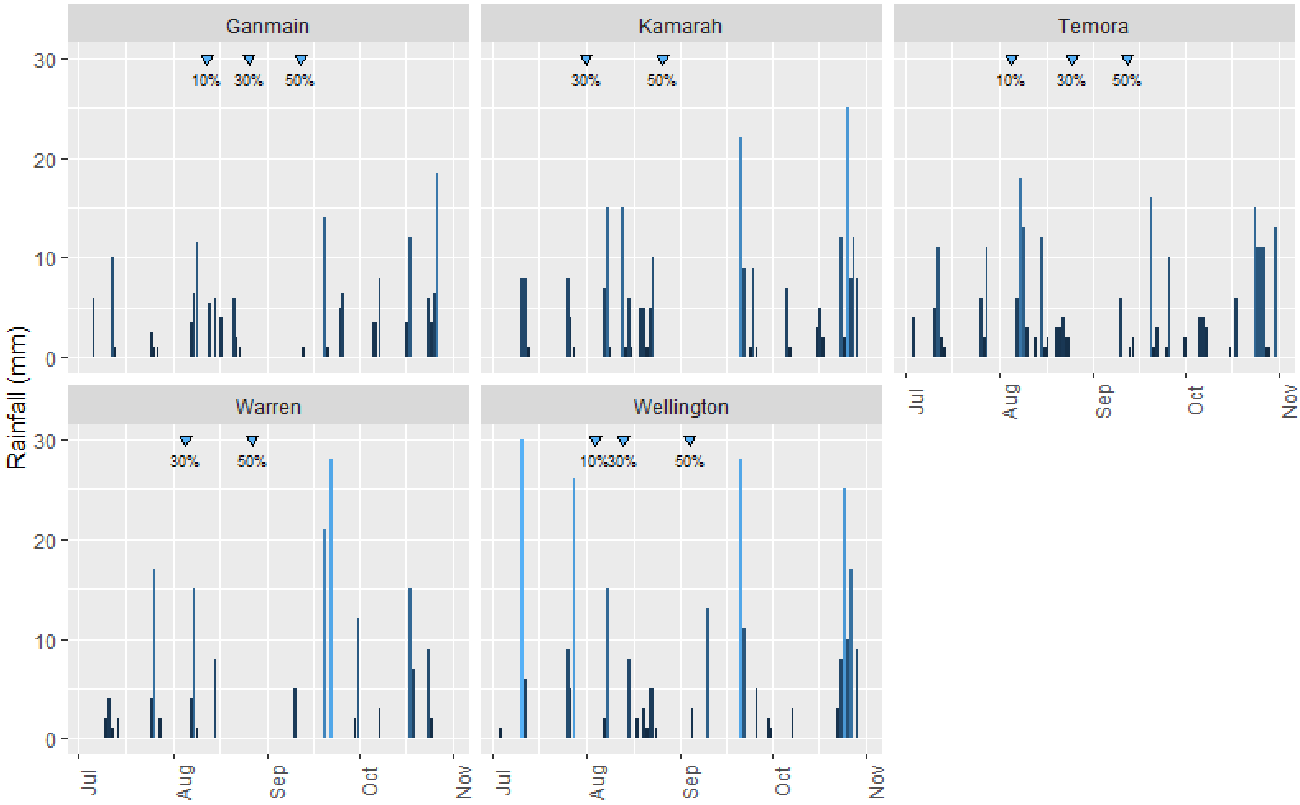

Figure 1. Daily rainfall received (vertical columns) and spray timings (inverted triangles) for five canola fungicide response trials conducted in NSW, 2020. Timings are bloom stage timing, e.g., 10% is 10% bloom stage.

Disease assessment

Diseases prevalence was assessed at one timing, targeted around 60-80 seed colour change (windrowing stage) with the methodologies detailed below.

Sclerotinia – two random sample areas of 1 m^2 were assessed in each plot, with the number of plants with Sclerotinia (basal, main stem and branch) counted along with the total number of plants in the assessment area to determine infection rates.

Upper canopy blackleg – a 0-4 score was allocated for the same two locations that were assessed for Sclerotinia:

- 0 = no infection observed
- 0.5 = at least one lesion found
- 1 = lesions present
- 2 = lesions common
- 3 = lesions common causing damage
- 4 = lesions common causing branch death

Alternaria black spot – the upper canopy blackleg scoring system was adapted for Alternaria with some minor tweaks:

- 0 = no infection observed
- 0.5 = at least one lesion found
- 1 = lesions present
- 2 = lesions common with 1-5% of pod/stem area infected

- 3 = lesions common with 5-15% of pod/stem area infected and low-level early pod senescence.
- 4 = lesions common with >15% of pod/stem area infected and high level of early pod senescence.

Powdery mildew – an assessment was made of the proportion of stem area infected with powdery mildew (two locations per plot as per Sclerotinia).

The trial results were analysed by ANOVA with 95% confidence level. Results are detailed in Tables four to eight below.

Results

Sclerotinia petal testing

Petal samples from 12 flowers from untreated areas were sent to the CCDM for determining the level of Sclerotinia present at each site. Sclerotinia was confirmed as present on petals at each of the five sites, with 100% of petals infected at Ganmain and Temora and down to 55% of petals infected at Wellington.

Table 3. Canola Sclerotinia petal infection rates at from five canola fungicide response trials conducted in NSW 2020.

Site	Petals infected (%)
Ganmain	100
Kamarah	78
Temora	100
Warren	87
Wellington	55

Geographic disease distribution

The highest levels of Sclerotinia infections were at the most south-eastern site Temora, where canola intensity and canopy moisture levels favoured disease development (Figure 2). There was no broader Sclerotinia infection of plants at Warren, despite petal tests confirming Sclerotinia as present at the site. Upper canopy blackleg (UCB) on branches ranged from only trace levels at the north-western site at Warren, to high levels of infection likely causing yield loss at the southern sites at Kamarah and Temora. Powdery mildew and Alternaria black spot (on pods) was most severe in the northern trials.

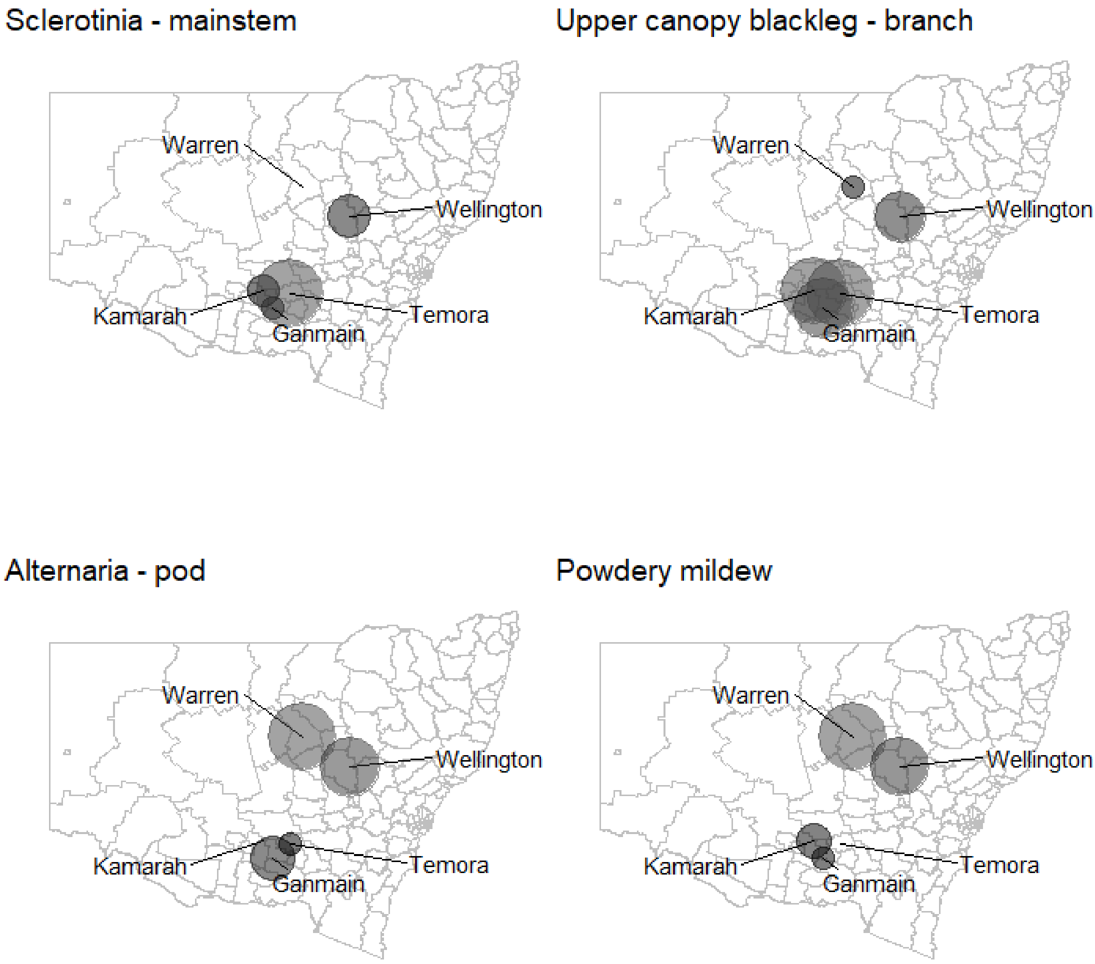

Figure 2. Severity of the diseases Sclerotinia stem rot (main stem), upper canopy blackleg (branch), Alternaria (pod) and powdery mildew across five canola fungicide response trials in NSW in 2020. Larger circles represent greater infection levels (data presented from untreated control). Data presented is dimensionless and no comparison can be made across diseases.

Ganmain

There was no grain yield response to the various fungicide treatments tested at Ganmain.

There was some reduction in Sclerotinia, UCB (branch), powdery mildew and Alternaria incidence, but disease levels were generally low. All fungicide treatments at the 30 and 50% bloom stage reduced Sclerotinia incidence compared to the untreated, but the 10% bloom fungicide treatment (Aviator Xpro only) did not reduce incidence. UCB (branch) was present but not at levels that would impact grain yield (rating of less than 2). Some reduction in incidence was achieved with single applications at 10 and 30% bloom applications of Aviator Xpro, second applications did not reduce incidence further than single spray treatments. A single application of Miravis Star at 30% also reduced incidence. Alternaria on pods was also common but not consequential, with incidence reduced by 50% bloom applications of Aviator Xpro. Powdery mildew was present at low levels, but disease incidence reduced further wherever Prosaro was applied at 50% bloom.

The Ganmain crop was HyTTec Trophy which has effective major gene (Group ABD) resistance to blackleg which may have reduced the severity of UCB infection. Although incidence on branches was easy to find, it was generally not at levels that would impact grain yield. There was only low level of blackleg on pods (data not shown). A further factor that reduced infection risk of this crop was that it flowered the latest of all the crops, with most (30-50% bloom) of the flowering period coinciding with a dry four-week period in late winter/early spring. For the period 1 July to 31 October, Ganmain had the least rainfall (160 mm) of the five sites.

Table 4. Canola grain yield, quality and disease response to fungicide in a crop of HyTTec Trophy at Ganmain 2020.

Fungicide treatment and timing (% bloom)*	Yield (t/ha)	Oil (%)	Sclero MS (%)	Sclero Br. (%)	UC BL Br.	Alt. pod	PM (%)
Aviator Xpro 650 mL/ha 10%	2.47	44.2	5.7	0.6	1.4	2.5	10
Aviator Xpro 650 mL/ha 30%	2.59	43.5	0.3	0	1.4	2.1	5.4
Prosaro 450 mL/ha 30%	2.56	42.9	0.3	0	1.7	2.5	2.9
Miravis Star 30%	2.61	43.9	0.5	0	1.4	2	5
Aviator Xpro 650 mL/ha 10% + Prosaro 450 mL/ha 50%	2.48	44	0.8	0	1.7	2.4	2.7
Aviator Xpro 650 mL/ha 30% + Prosaro 450 mL/ha 50%	2.56	43.5	0.6	0	1.4	2.4	1.2
Prosaro 375 mL/ha 30% + Prosaro 375 mL/ha 50%	2.61	43.4	0	0	1.9	2.2	1.5
Aviator Xpro 550 mL/ha 30% + Aviator 550 mL/ha 50%	2.52	43.6	0	0	1.4	1.5	5.6
Aviator Xpro 650 mL/ha 50%	2.53	43.9	0.6	0.3	1.7	1.9	4.5
Prosaro 450 mL/ha 50%	2.47	43.8	0.3	0	2.1	2.8	1.6
Untreated	2.49	42.9	3.3	1.8	2.2	2.8	9.1
l.s.d. (*p<0.05*)	n.s.	1	1.2	0.5	0.8	0.5	3.2

** Product recommendations for timing of application in canola vary. Not all products have claims at the 10% timing used in these trials or for all diseases evaluated (no products have claims for control of Alternaria or powdery mildew in canola). Check product labels for details.*

Sclero MS = Proportion of plants with Sclerotinia infection on the main stem. Sclero Br. = proportion of plants with Sclerotinia infection on a branch. UC BL Br = Upper canopy blackleg branch infection with protocol outlined in methodology. Alt. pod = Alternaria pod infection score with protocol outlined in methodology. PM (%) is proportion of stem are infected with powdery mildew. Shaded cells indicate results are significantly better than untreated i.e., less disease or more yield/oil.

Kamarah

There was a positive grain yield response (up to 0.4 t/ha) to all single-spray treatments at Kamarah except Prosaro at 50% bloom. There was no additional benefit of two-spray strategies over one fungicide spray.

Sclerotinia (main stem) infection was low, but all treatments reduced the incidence of the disease except the single applications of Prosaro (both 30 and 50% bloom) or Aviator Xpro at 50% bloom. Fungicide application at 30% bloom (except Veritas) reduced UCB (branch) infection, from levels that would likely reduce yield in the untreated control. All fungicide treatments provided some (but not complete) reduction in the incidence of powdery mildew.

The period between 30 and 50% bloom was relatively wet at Kamarah which may have partly contributed to higher branch blackleg infection than Ganmain. A further contributing factor is that the cultivar 44Y90 CL, despite having effective crown canker resistance, does not have effective major gene resistance.

Table 5. Canola grain yield, quality, and disease response to fungicide in a crop of 44Y90 CL at Kamarah 2020.

Fungicide treatment and timing (% bloom)*	Yield (t/ha)	Oil (%)	Sclero MS (%)	Sclero Br. (%)	UCI Br.	Alt. pod	PM (%)
Aviator Xpro 650 mL/ha 30%	2.87	42.7	0	0	1.9		4.1
Prosaro 450 mL/ha 30%	2.89	43.3	0	0	2.2		5
Veritas 1 L/ha 30%	2.71	42.3	0.5	0	3.1		8.6
Miravis Star 30%	2.70	42.7	0	0	1.9		4.9
Aviator Xpro 650 mL/ha 30% + Prosaro 450 mL/ha 50%	2.78	42.5	0	0	1.5		3.2
Prosaro 375 mL/ha 30% + Prosaro 375 mL/ha 50%	2.70	43.1	0	0	2		4.9
Aviator Xpro 550 mL/ha 30% + Aviator 550 mL/ha 50%	2.75	42.7	0	0	1.6		3.4
Aviator Xpro 650 mL/ha 50%	2.74	42.6	4.4	0.6	2.8		7.5
Prosaro 450 mL/ha 50%	2.67	42.6	3.4	0	2.6		7.4
Untreated	2.49	42.7	2.8	0	3.4		15
l.s.d. (*p<0.05*)	0.20	1	1.1	0.5	0.6		4.2

** Product recommendations for timing of application in canola vary. Not all products have claims at the 10% timing used in these trials or for all diseases evaluated (no products have claims for control of Alternaria or powdery mildew in canola). Check product labels for details.*

Sclero MS = Proportion of plants with Sclerotinia infection on the main stem. Sclero Br. = proportion of plants with Sclerotinia infection on a branch. UC BL Br = Upper canopy blackleg branch infection with protocol outlined in methodology. Alt. pod = Alternaria pod infection score with protocol outlined in methodology. PM (%) is proportion of stem are infected with powdery mildew Shaded cells indicate results are significantly better than untreated i.e., less disease or more yield/oil.

Temora

There was a positive grain yield response of up to 0.6 t/ha at Temora. Aviator at 10 and 30% bloom but not 50% bloom improved yields as did Miravis Star at 30% bloom. Prosaro at 30% did not increase yield but did at 50% bloom. Most (but not all) two-spray treatments improved yield.

Sclerotinia infection was highest of all five sites at Temora, but still only a moderate infection level of 12.2% of main stems infected where no fungicide was applied. Aviator Xpro at 10 and 50% bloom, and Veritas at 30% bloom did not reduce Sclerotinia incidence. Aviator Xpro at 10% followed by Prosaro at 50% bloom did not improve yield. Application of Aviator Xpro at 10 and 30%, Miravis Star at 30% bloom and all the two spray strategies reduced UCB (branch), but the best treatment still only reduced the score to a range from 1.5 to 2.1. Application of Prosaro and Veritas at 30% bloom and Prosaro and Aviator Xpro at 50% bloom did not reduce branch blackleg. Miravis Star at 30%, Aviator Xpro followed by Aviator Xpro (30 and 50% bloom) or Prosaro or Aviator Xpro at 50% bloom reduced Alternaria incidence on the pods but did not give full control.

A two-spray strategy generally provided good reductions of both Sclerotinia and blackleg, but no two-spray treatment resulted in higher grain yield than a single application of Aviator Xpro at 30% bloom.

Table 6. Canola grain yield, quality, and disease response to fungicide in a crop of 45Y91 CL at Temora 2020.

Fungicide treatment and timing (% bloom)*	Yield (t/ha)	Oil (%)	Sclero MS (%)	Sclero Br. (%)	UCI Br.	Alt. pod	PM (%)
Aviator Xpro 650mL/ha 10%	3.50	43.2	13.8	1.5	1.5	2	*Nil*
Aviator Xpro 650 mL/ha 30%	3.73	43.5	3.1	1.5	2.1	1.9	*Nil*
Prosaro 450 mL/ha 30%	3.37	43.6	2.6	0.3	2.9	2.1	*Nil*
Veritas 1 L/ha 30%	3.45	42.9	9.9	2	2.9	2.1	*Nil*
Miravis Star 30%	3.58	43.2	2.3	0	2.1	1.4	*Nil*
Aviator Xpro 650 mL/ha 10% + Prosaro 450 mL/ha 50%	3.73	42.6	6.1	0.3	1.7	1.9	*Nil*
Aviator Xpro 650 mL/ha 30% + Prosaro 450 mL/ha 50%	3.46	43.1	1	0	1.9	1.6	*Nil*
Prosaro 375 mL/ha 30% + Prosaro 375 mL/ha 50%	3.70	43.5	1	0	2.1	1.8	*Nil*
Aviator Xpro 550 mL/ha 30% + Aviator 550 mL/ha 50%	3.71	43	1.3	0.3	2	1.6	*Nil*
Aviator Xpro 650 mL/ha 50%	3.45	43.1	7.4	0.8	2.6	1.2	*Nil*
Prosaro 450 mL/ha 50%	3.62	43.6	4.6	0.8	3.3	2.1	*Nil*
Untreated	3.07	43.7	12.2	3.6	3.1	2.4	*Nil*
l.s.d. ($p<0.05$)	0.44	0.8	6.3	1.7	0.7	0.7	n.s.

** Product recommendations for timing of application in canola vary. Not all products have claims at the 10% timing used in these trials or for all diseases evaluated (no products have claims for control of Alternaria or powdery mildew in canola). Check product labels for details.*

Sclero MS = Proportion of plants with Sclerotinia infection on the main stem. Sclero Br. = proportion of plants with Sclerotinia infection on a branch. UC BL Br = Upper canopy blackleg branch infection with protocol outlined in methodology. Alt. pod = Alternaria pod infection score with protocol outlined in methodology. PM (%) is proportion of stem are infected with powdery mildew. Shaded cells indicate results are significantly better than untreated i.e., less disease or more yield/oil.

Warren

No fungicide treatments resulted in a significant increase in grain yield.

There was no Sclerotinia infection at Warren and low (inconsequential) levels of upper canopy blackleg. The main diseases apparent were powdery mildew and Alternaria infection on pods and stems. Powdery mildew infection was the highest of all five sites, with 67% of stem/branch area infected with powdery mildew by crop maturity (windrow timing) in the untreated control. Fungicide treatments with Prosaro applied at 50% bloom reduced powdery mildew incidence to close to very low levels with no benefit to yields (Prosaro does not claim control of powdery mildew in canola on its label). Alternaria infection on pods was high with only two-spray fungicide treatments providing a small level of control. The Warren site also had high levels of Alternaria on stems/branches, with all fungicide treatments giving some reduction in incidence (data not shown). Unlike branch blackleg observed at other sites, Alternaria did not manifest into cankers that eventually resulted in branch death but were usually superficial. It is difficult to ascertain if Alternaria infection on pods had any effect on grain yield, as no fungicide treatment resulted in clean pods. It is likely that fungicide would need to be applied when all pods are formed (e.g., end of flowering) to achieve good control of Alternaria, but all fungicide products need to be applied by the 50% bloom stage.

Table 7. Canola grain yield, quality, and disease response to fungicide in a crop of HyTTec Trophy at Warren 2020.

Fungicide treatment and timing (% bloom)*	Yield (t/ha)	Oil (%)	Sclero MS (%)	Sclero Br. (%)	UCI Br.	Alt. pod	PM (%)
Aviator Xpro 650 mL/ha 30%	3.72	41.3			0	3.6	19.5
Aviator Xpro 800 mL/ha 30%	3.60	41.1			0	3.6	17.1
Prosaro 450 mL/ha 30%	3.52	41			0	4	17.7
Veritas 1 L/ha 30%	3.39	40.2			0	3.6	20.6
Miravis Star 30%	3.56	40			0	4	43.1
Aviator Xpro 650 mL/ha 30% + Prosaro 450 mL/ha 50%	3.70	39.6	*Nil*	*Nil*	0	3	2.5
Prosaro 375 mL/ha 30% + Prosaro 375 mL/ha 50%	3.75	40.6			0	4	5.3
Aviator Xpro 650 mL/ha 50%	3.43	40.9			0.2	3.2	16.9
Prosaro 450 mL/ha 50%	3.47	40.5			0.2	3.6	5.8
Untreated	3.43	40.5			0.2	4	67.4
l.s.d. (*p<0.05*)	0.35	1.6	*n.s.*	*n.s.*	*0.1*	0.4	14.8

** Product recommendations for timing of application in canola vary. Not all products have claims at the 10% timing used in these trials or for all diseases evaluated (no products have claims for control of Alternaria or powdery mildew in canola). Check product labels for details.*

Sclero MS = Proportion of plants with Sclerotinia infection on the main stem. Sclero Br. = proportion of plants with Sclerotinia infection on a branch. UC BL Br = Upper Canopy Blackleg Branch infection with protocol outlined in methodology. Alt. pod = Alternaria pod infection score with protocol outlined in methodology. PM (%) is proportion of stem are infected with powdery mildew. Shaded cells indicate results are significantly better than untreated i.e., less disease or more yield/oil.

Wellington

There was a positive (0.2-0.3 t/ha) grain yield response for two of two-spray fungicide treatments, but no single-spray treatments increased yield. Sclerotinia infection levels were low and upper canopy blackleg infection levels were moderate at Wellington. All fungicide treatments except Prosaro and Veritas at 30% bloom provided control of Sclerotinia and upper canopy blackleg branch incidence. Powdery mildew incidence was moderate with best control where Prosaro was applied at the 50% bloom stage. Alternaria infection levels in the untreated control were high on pods (score of 3.9) and stems (score of 4, data not shown for stems) with best reductions from the single Aviator Xpro 50% bloom application (score of 1.4). Fungicide application did a better job of reducing Alternaria on the stems than on pods, again due to the inability to spray fungicide beyond 50% bloom stage to protect all pods. The large differences between Alternaria scores on the stems did not manifest into major differences in grain yield, indicating that Alternaria may have only been superficial.

Table 8. Canola grain yield, quality and disease response to fungicide in a crop of Victory V75-03CL at Wellington 2020.

Fungicide treatment and timing (% bloom)*	Yield (t/ha)	Oil (%)	Sclero MS (%)	Sclero Br. (%)	UCI Br.	Alt. pod	PM (%)
Aviator Xpro 650mL/ha 10%	3.78	43.1	1.1	0	0.7	3.4	24.4
Aviator Xpro 650 mL/ha 30%	3.71	42.9	0.6	0	0.7	3.5	21
Aviator Xpro 800 mL/ha 30%	3.75	43.4	0.4	0.4	0.9	3.1	15.9
Prosaro 450 mL/ha 30%	3.51	43	5.8	0.3	1.9	3.6	15.2
Veritas 1 L/ha 30%	3.62	43.1	3.5	3.3	1.4	3.6	18.2
Aviator Xpro 650 mL/ha 10% + Prosaro 450 mL/ha 50%	3.90	43.3	0	0	0.4	3.3	4.4
Aviator Xpro 650 mL/ha 30% + Prosaro 450 mL/ha 50%	3.77	42.7	0.5	0	0.7	3.4	8.2
Prosaro 375 mL/ha 30% + Prosaro 375 mL/ha 50%	3.81	43.2	0.8	0.3	0.7	3.2	5.2
Aviator Xpro 650 mL/ha 50%	3.76	43.7	1.1	0	1.1	2.1	12.5
Prosaro 450 mL/ha 50%	3.77	42.5	0.9	0.4	0.8	3	6.1
Untreated	3.64	43	4	1.7	1.9	3.9	18.8
l.s.d. (*p<0.05*)	0.17	0.9	2	2.2	0.6	0.6	8.7

** Product recommendations for timing of application in canola vary. Not all products have claims at the 10% timing used in these trials or for all diseases evaluated (no products have claims for control of Alternaria or powdery mildew in canola). Check product labels for details.*

Sclero MS = Proportion of plants with Sclerotinia infection on the main stem. Sclero Br. = proportion of plants with Sclerotinia infection on a branch. UC BL Br = Upper Canopy Blackleg Branch infection with protocol outlined in methodology. Alt. pod = Alternaria pod infection score with protocol outlined in methodology. PM (%) is proportion of stem are infected with powdery mildew. Shaded cells indicate results are significantly better than untreated i.e., less disease or more yield/oil.

Fungicide economics

To determine the economic benefit of the fungicide treatments, grain yield was multiplied by price (allowing for oil increments) and costs of fungicide product and application costs were subtracted. This partial gross margin was then analysed as a variate in the same way that grain yield was analysed (Miravis Star was not included in the economic analysis as it has not yet commercially available).

We assumed a price of:

- $550/tonne for canola (+/- 1.5% for each 1% oil above or below 42%)
- $54.50/L Aviator Xpro
- $74.50/L Prosaro
- $21/L Veritas
- $13/ha application cost

At Ganmain there was no (statistical) difference in the partial gross margin (gross income less treatment and application costs) of any treatment compared to the untreated control. There was a higher partial gross margin at Kamarah only from the application of both Aviator Xpro and Prosaro at 30% bloom. At Temora, the highest partial gross margin was from a single spray of Aviator Xpro at 30% bloom. At both Warren and Wellington, there was no economic benefit of any fungicide treatment compared to the untreated control.

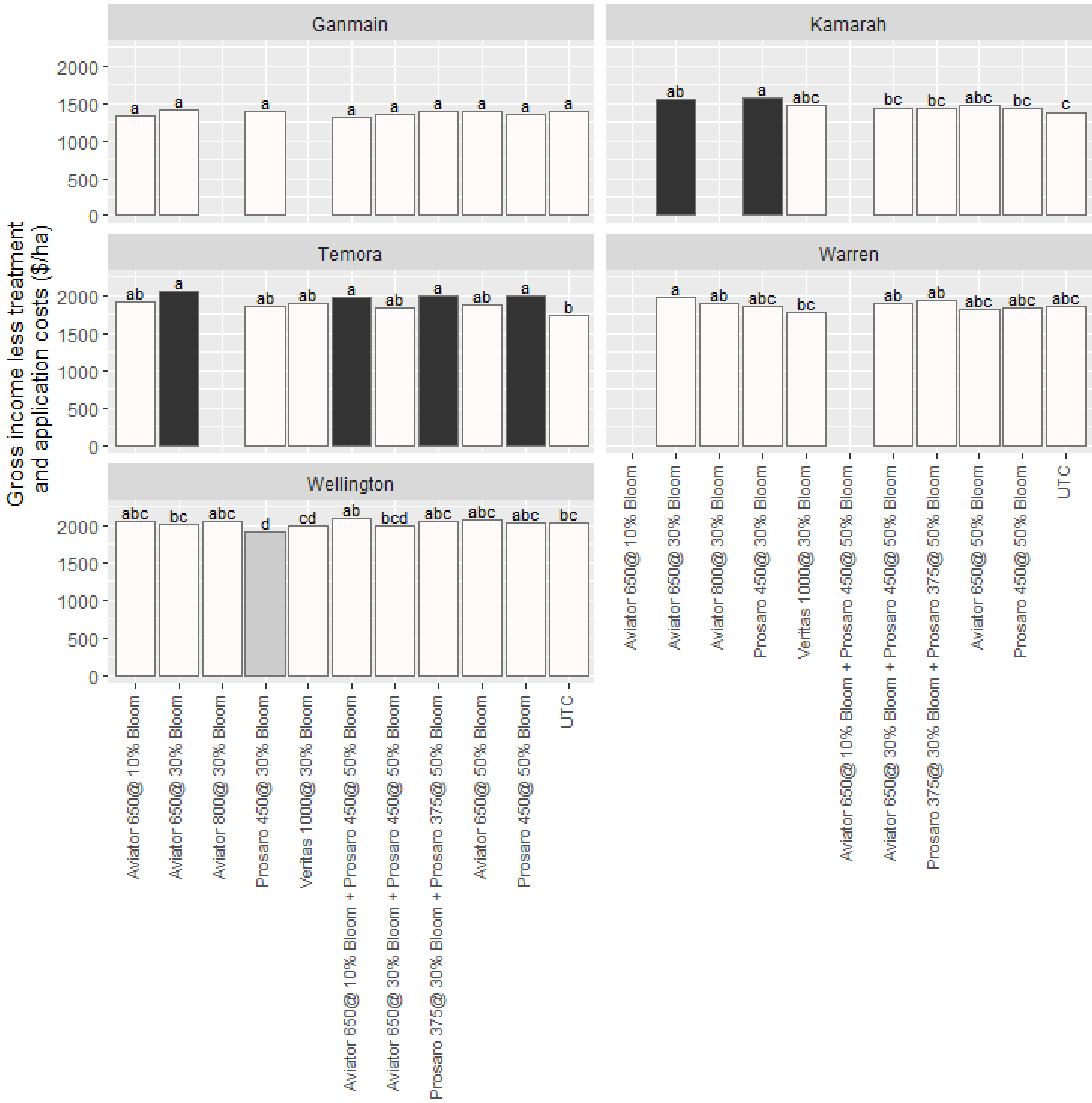

Figure 3. Partial gross margin (gross income less fungicide product and application costs) of fungicide treatments across five sites in NSW in 2020. Treatments with the same letter are not significantly different at p=0.05. Treatments in black are significantly higher than untreated control (UTC) and treatments in grey are significantly lower than UTC.

Discussion and conclusion

Many southern and central NSW canola crops in low-medium rainfall zones had a foliar fungicide applied to them in 2020. The primary driver was protection from Sclerotinia stem rot predicted by a wet first half to the cropping year leading to higher yield potential and medium-term forecasts predicting above average rain through spring. The secondary concern was UCB, especially in southern regions. The presence of Sclerotinia spores was confirmed by petal testing at all trial sites and blackleg was observed at all sites. Despite presence of these diseases at all sites, improvements in grain yield were not common or consistent and economic benefits from fungicide were evident at only two sites.

Petal testing indicated that Sclerotinia inoculum was present at all sites. That visual inspections at Warren and Wellington did not find any apothecia would tend to indicate that infections may have come from neighbouring paddocks. On the other hand, the presence of inoculum was not a good predictor of the ensuing levels of infection.

At all sites, a period of dry weather was experienced through late August and early September which may have limited the development of Sclerotinia in the canopy, however, all sites received good rainfall thorough the early flowering period and again during the late flowering period at most sites.

However, Sclerotinia and blackleg were not the only diseases present in these trials and, although separate assessments were made on the impact of fungicide treatment on the multiple diseases present, it is impossible to attribute yield response (where observed) to any one disease. Yield responses may have been due to reduction in infection of one or more diseases.

Sclerotinia and blackleg were at low levels in the two northern trials (Warren and Wellington) whereas powdery mildew and Alternaria infection were relatively high but spraying fungicide did not provide an economic benefit at these two sites. (None of the products tested have label claims for these two diseases in canola).

Some reduction in Alternaria was achieved with fungicides but it was difficult to ascertain the level of yield loss as even a two-spray strategy was not enough to fully protect pods. The latest spray timing on label is 50% bloom and at this stage only 20-30% of pods have formed. Powdery mildew was a talking point at windrowing time in many crops in the central-west. We found good reductions in in symptoms where Prosaro was applied at 50% bloom yet there did not appear to be significant yield losses even at high levels of infection. Prosaro does not have a label claim for control of powdery mildew in canola.

There was a more compelling case for the economic benefit of fungicides in two of the three southern sites, but not with all treatments. Both responsive sites (Kamarah and Temora) were in cultivars without effective major gene resistance to blackleg, so yield response may have been due to upper canopy blackleg (branch) infection as well as Sclerotinia (especially at Temora). A single spray of Aviator Xpro at 30% bloom provided the most consistent economic benefit in the two responsive southern sites, at Temora returning a net $323/ha net advantage over the untreated.

Overall, despite the presence of several diseases including Sclerotinia and UCB and high yield potential, positive responses to fungicide applications were not universal across sites. In hindsight the dryer conditions in late Autumn to early Spring may have limited disease progression and hence reduced the necessity for fungicides. However, as fungicides are prophylactic, growers and advisors can only work with the information they had at the time.

Many growers and advisors saw the application of fungicide as an insurance policy rather than as an investment and were comfortable knowing they had some of the best crops they had ever grown protected from the potential negative yield effects of key fungal diseases. There are several other 'investments' that could be made into a canola crop where returns are more predictable (such as nitrogen) and ideally the investments that give a reliable return should be addressed before spending more money on 'insurance'.

However, given that 2020 was such a good season with very high yield potential, and that economic benefits were not always present, should give growers the confidence that in seasons with only 'average' grain yield potential, expenditure on fungicide may not be justified and money may be better invested elsewhere.

Management factors that growers can implement in 2021 to reduce fungicide requirement during the flowering period include:

- Select cultivars with effective major gene blackleg resistance. Monitor updates to the GRDC Blackleg Management Guide to guide decision making

- Match phenology and sowing date so that crops do not flower too early. Early flowering will usually result in greater exposure to disease - especially upper canopy blackleg
- Closely monitor short-term forecasts as diseases require moisture for infection
- Consider using some of the decision support tools that may quantify the risks of canola diseases and the need for fungicide applications.
    - One example promoted by Bayer can be found at- https://www.crop.bayer.com.au/-/media/bcs-inter/ws_australia/use-our-products/product-resources/prosaro/prosaro_420_sc-factsheet-sclerotinia_control.pdf
    - Download the SclerotiniaCM and BlacklegCM decision support Apps for your tablet or iPad device
- Avoid sowing canola in or near paddocks that have had high levels of disease infection recently
- When a fungicide is required, apply at the correct time (~30% bloom) and with good coverage to avoid needing a second fungicide.

By reducing the need for fungicide, growers may be able to invest in other inputs where higher returns are guaranteed.

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Contact details

Maurie Street
Grain Orana Alliance
PO Box 2880, Dubbo
Ph: 02 6887 8258
Email: maurie.street@grainorana.com.au

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NSW cereal diagnostics and enquiries – the 2020 winner is……?

Steven Simpfendorfer[1], Brad Baxter[2] and Andrew Milgate[2]

[1] *NSW DPI Tamworth*
[2] *NSW DPI Wagga Wagga*

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correct diagnosis, leaf diseases, soil-borne diseases, wheat, barley

GRDC code

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Take home messages

- Cereal diseases were prevalent in 2020 with favourable climatic conditions. Hence, in combination with increased cereal stubble loads, pathogen levels are likely to be elevated in 2021
- However, steps can be taken to minimise impacts which include:
  - Remember the basics of disease management – think disease triangle!
  - Know before you sow (e.g. PREDICTA®B or stubble tests) – inoculum levels
  - Varietal resistance – reduce host susceptibility
  - Manipulate canopy microclimate or stress during grain filling – environmental conditions
- NSW DPI plant pathologists can help with correct diagnosis and management options.

Introduction

A 'no-additional charge' cereal diagnostic service is provided to NSW cereal growers and their advisers under projects BLG207 and BLG208 as part of the GAPP co-investment. Evidence based methods are used to confirm diagnosis which include a combination of visual symptoms, crop management history, distribution in paddock and recovery/identification of the causal pathogens (microscopy, humid chamber or plating). Any suspect virus samples are confirmed using ELISA antibody testing at NSW DPI Elizabeth Macarthur Agricultural Institute at Menangle.

Wheat, barley and oat rust samples (stripe, leaf and stem) are sent to the Australia Cereal Rust Control Program (ACRCP). The submission of samples to ACRCP facilitates the tracking of pathotype populations and distribution across the cropping belt of NSW and Australia. This includes a new interactive map (Australian Cereal Rust Survey 2020 Sample Map - Google My Maps) regularly updated throughout the growing season by the ACRCP. Growers can access this resource to see which pathotypes dominate in their region. This can be very important to guide in-crop management decisions given five different stripe rust pathotypes were present at varying levels across NSW in 2020. Individual wheat varieties can have vastly different reactions to these pathotypes, so knowing which ones are dominant, where and when, can guide appropriate seasonal in-crop management.

The projects also record disease enquiries received and resulting management advice provided to growers and advisers throughout each season. These project activities support NSW cereal producers in correct diagnosis of diseases during the season with resulting independent advice on appropriate management strategies to limit economic impacts. This is assisting to limit the unnecessary application of in-crop fungicides by growers.

Which diseases dominated in 2019 and 2020?

Collation of this data across NSW provides an annual 'snapshot' of the key biotic and abiotic constraints to cereal production (Table 1).

Table 1. Cereal diagnostics and enquiries processed across NSW in 2019 and 2020. Disease/issues are ranked in order of frequency in 2020

Disease/issue	2020	2019
Stripe rust (wheat)	194	13
Spot form of net blotch	65	32
Physiological/melanism	65	10
Scald	65	4
Fusarium crown rot	61	14
Wheat powdery mildew	53	1
Frost damage	45	4
Leaf rust (wheat)	35	2
Other non-disease (e.g. soil constraint, leaf blotching)	34	24
Bacterial blight (other cereals)	30	0
Rusts crown and stem (oats)	29	4
Herbicide	28	6
Net form of net blotch	23	0
Bacterial blight (oats)	22	3
Barley grass stripe rust	20	1
Barley yellow dwarf virus	19	1
Septoria tritici blotch	17	13
Nutrition	16	2
Take-all	16	1
Rhizoctonia	12	7
Barley powdery mildew	12	0
Yellow leaf spot	10	4
Fusarium head blight	10	0
Loose smut	9	1
Seedling root disease complex (Pythium, crown rot, Rhizo,Take-all)	8	2
Septoria oats	3	2
Wheat streak mosaic virus	3	1
Common root rot	2	3
Rye grass rust	2	0
Ergot	1	0
Red leather leaf	1	7
Sclerotium rolfsii	1	2
Spot blotch	1	0
Ring spot	0	1
Total	**912**	**165**

Not surprisingly, individual seasons have a strong influence on the level of cereal diagnostic support provided to NSW growers/advisers, with over five-times the number of activities in the wetter 2020 season compared with much drier conditions experienced in 2019 (Table 1). This increase was primarily due to more conducive conditions for the development of a range of cereal leaf diseases (e.g. rusts, scald, net-blotches, Septoria) in 2020 (537 samples) compared with 2019 (77 samples).

The four main cereal diseases in 2020 were wheat stripe rust (widespread distribution of newer Yr198 pathotype), spot form of net blotch in barley, scald in barley and Fusarium crown rot in different winter cereal crops. In comparison, the four main cereal diseases in 2019 were spot form of net blotch, Fusarium crown rot, wheat stripe rust and Septoria tritici blotch (Table 1).

Interestingly, the levels of yellow leaf spot (*Pyrenophora tritici-repentis*) diagnosed in both seasons were relatively low. However, wheat samples with leaf blotches or mottling were submitted each year, suspected to be caused by yellow leaf spot. There is an ongoing difficulty with correct diagnosis of this particular leaf disease by growers and their advisers, often confused with Septoria tritici blotch (*Zymoseptoria tritici*), Septoria nodorum blotch (*Stagonospora nodorum*) and physiological responses to abiotic stress (e.g. frost yellowing, N mobilisation, herbicide damage).

The 2020 season also highlighted that root diseases like take-all, which have not been seen at damaging levels for many years can quickly re-emerge at significant levels when conducive conditions occur. Conversely, Fusarium crown rot remains a significant issue across seasons.

The number of rust and powdery mildew samples received from susceptible wheat varieties in 2020 highlights the importance of genetic resistance as a component of integrated disease management systems. Susceptible varieties are more reliant on fungicide applications to limit disease levels and associated yield loss, which can increase the risk of fungicide resistance developing. The resistance selected may not necessarily be in the main pathogen targeted by the fungicide applications. For example, reliance on fungicide applications in stripe rust susceptible varieties could inadvertently select for fungicide resistance in wheat powdery mildew populations when they co-infect plants. Preliminary research conducted in collaboration with Curtin University's Centre for Crop Disease Management (CCDM) in 2020, unfortunately indicates issues with reduced sensitivity to azoles (DMIs, Group 3) and resistance to strobilurin (QoIs, Group 11) fungicides are already widespread in wheat powdery mildew populations in NSW and Victoria.

Are you getting a correct diagnosis?

Importantly, 21% of activities in 2020 and 28% in 2019 were not related to disease. These samples were either diagnosed as being plant physiological responses to stress, frost damage, herbicide injury, related to crop nutritional issues or other non-disease issues. All of these samples were submitted as suspected of having disease issues. This highlights the ongoing importance of the diagnostic service provided by these projects to NSW growers and their advisers to support correct identification and implementation of appropriate management strategies. Never be afraid to get a second opinion from a plant pathologist, we are here to help (see contact details).

Management in 2021 – remember the basics!

Showing our ages here by referring back to the good old 'disease triangle', my mentors would be proud! Disease levels in 2021 will still be based around the disease triangle, which requires a combination of pathogen inoculum, susceptible host and environmental conditions conducive to disease development. Given the elevated incidence of a wide range of cereal diseases across NSW in 2020 (Table 1), inoculum levels of a range of cereal pathogens and hence disease risk in 2021 will be higher than previous seasons. Each of the three components of the disease triangle should be considered when implementing management strategies to minimise losses and determine if fungicide application is warranted in 2021.

1. Inoculum levels

The first step is 'know before you sow'. PREDICTA®B testing remains the gold standard for a quantitative assessment of a wide range of cereal pathogens and associated risk of both soil-borne and leaf diseases. Refer to [the PREDICTA B sampling protocol (https://pir.sa.gov.au/__data/assets/pdf_file/0007/291247/Sampling_protocol_PreDicta_B_Northern_regions.pdf)](https://pir.sa.gov.au/__data/assets/pdf_file/0007/291247/Sampling_protocol_PreDicta_B_Northern_regions.pdf). NSW DPI is alternatively offering a free cereal stubble testing service prior to sowing in 2021 (Jan-Apr) aimed primarily at determining Fusarium crown rot risk levels in cereal-on-cereal situations (contact Steven Simpfendorfer for details).

The disease risk associated with inoculum levels can be quite different with various pathogens depending on their capacity for wind dispersal. For example, stubble and soil borne pathogens which cause Fusarium crown rot, take-all and Rhizoctonia root rot are not dispersed by wind, hence risk from inoculum is confined to an individual paddock. Consequently, crop rotation to a non-host pulse or oilseed crop breaks the disease triangle. Stubble borne leaf pathogens, which cause net blotch or scald in barley, yellow spot or Septoria tritici blotch in wheat or powdery mildew, have limited wind dispersal (i.e. metres), so again crop rotation largely reduces disease risk and especially at early growth stages. Conversely, rusts are airborne (i.e. kilometres) so crop rotation is irrelevant to disease risk.

Seed borne infection should also be considered with some pathogens such as bacterial blights, scald, net-form of net blotch, smuts and bunts. Sourcing clean seed for sowing in 2021, that is, not from crops infected in 2020, is important to reduce risk of these diseases.

With stripe rust, reducing or delaying the onset of an epidemic significantly reduces disease pressure. Rust spores are readily wind borne and are commonly referred to as 'social diseases' (i.e. 'we are all in this together'). Hence, co-ordinated management across a region can have real benefits for all. Controlling volunteer wheat plants at least three weeks prior to first planting of crops limits the 'green bridge' survival and delays epidemic onset. In-furrow (e.g. flutriafol) and seed treatments (e.g. fluquinconazole) fungicides provide extended protection from stripe rust early in the season delaying epidemic onset. This can be particularly important when early sowing susceptible long season wheat varieties (e.g. DS Bennett⦹), which can place early disease pressure on later sown susceptible main season varieties.

Growers should also be aware that stubble management practices can also influence inoculum dispersal. For example, inter-row sowing between intact standing cereal stubble reduces the level of Fusarium crown rot infection. However, cultivating or mulching infected cereal stubble prior to sowing can spread Fusarium inoculum more evenly across a paddock and potentially into the surface layers of the soil where plant infection primarily occurs. Volunteer cereal plants and grass weeds over the summer fallow period can also be a major source of increased inoculum of Fusarium crown rot, take-all and Rhizoctonia leading into sowing in 2021.

2. Host susceptibility

Relatively self-explanatory? If you do not want cereal disease issues, then sow a non-host pulse or oilseed break crop. However, if considering cereal-on-cereal, key points are:

1. Make sure you are using the latest varietal resistance ratings especially to newer pathotypes of stripe rust. Many growers got caught out on this with durum wheats and DS Bennett in 2020. Improved levels of resistance to leaf diseases reduces reliance on foliar fungicides
2. If multiple pathogen risks then hedge towards improved resistance to the more yield limiting, harder to control and/or historically bigger issue in your area. This could be quite different between rainfall zones or dryland vs irrigated situations
3. Barley, bread wheat, durum, oats and triticale are NOT break crops for each other! They all host Fusarium crown rot, take-all and Rhizoctonia. Barley tends to be more susceptible to

Rhizoctonia root rot, but its earlier maturity can provide an escape from late season stress which reduces yield loss to Fusarium crown rot

4. Rusts and necrotrophic leaf diseases (net blotches, yellow spot, Septoria) tend to be crop specific. However, note that in wetter seasonal finishes it appears that some of these necrotrophic leaf pathogens have the potential to saprophytically colonise other cereal species.

3. Environmental conditions

Largely in the 'lap of the gods'? Certainly more limited options here but growers should be aware that subtle microclimate differences within cereal canopies can have a large influence on cycling of leaf diseases. Crash grazing of dual purpose wheat varieties not only reduces any early stripe rust inoculum, but also opens the canopy to reduce the duration of leaf wetness and lowers humidity. This reduces conduciveness to leaf diseases. Higher nitrogen levels can also exacerbate rusts and powdery mildew through thicker canopies creating a more favourable microclimate for these pathogens. However, leaf nitrate also serves as a food source for these biotrophic leaf pathogens.

Yield loss from Fusarium crown rot infection, largely through the expression of the disease as whiteheads, is strongly related to moisture and temperature stress during grain filling. Although growers cannot control rainfall during this period, there is the potential to limit the probability of stress through earlier sowing (matched to varietal maturity and frost risk), maximising soil water storage during fallow periods (stubble cover + weed control), addressing other biotic (e.g. nematodes, Rhizoctonia) or abiotic (e.g. acidity, nutrition, residual herbicides etc.) constraints to root development and canopy management. Recent (last two weeks) and predicted weather conditions (next 2-4 weeks) should also be considered with in-crop leaf disease management decisions in susceptible varieties around key growth stages for fungicide application of GS30-32 (1st node), GS39 (flag leaf emergence) and GS61 (flowering).

Conclusions

Overall the 2020 season was fairly good across a large proportion of NSW with cereal diseases present at higher frequencies than recent seasons. Hopefully 2021 provides another favourable year for cereal production. Cereal disease risk is likely to be higher due to pathogen build-up in 2020 and the likely increased area of cereal-on-cereal in 2021. Calm considered and well planned management strategies in 2021 can minimise disease levels. NSW DPI is here to support correct diagnosis and discuss management options prior to sowing and as required throughout the season. Let's get back to cereal disease management basics in 2021 and leave any lingering 'pandemic panic' from 2020 behind.

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Contact details

Steven Simpfendorfer
NSW DPI, 4 Marsden Park Rd, Tamworth, NSW 2340
Ph: 0439 581 672
Email: steven.simpfendorfer@dpi.nsw.gov.au
Twitter: @s_simpfendorfer or @NSWDPI_AGRONOMY

Andrew Milgate
NSW DPI, Pine Gully Rd, Wagga Wagga, NSW 2650
Ph: 02 6938 1990
Email: andrew.milgate@dpi.nsw.gov.au

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The economics of managing Ascochyta in chickpea when disease occurs at different growth stages and implications for spray timing

Leigh Jenkins[1], Kevin Moore[2] and Steven Harden[2]

[1] *NSW DPI, Trangie*
[2] *NSW DPI, Tamworth*

Key words

chickpea, Ascochyta, management, gross margin, profitability

GRDC code

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Take home messages

- Impact of Ascochyta at different growth stages was investigated in a 2020 field experiment at Trangie with varieties Kyabra⫯, PBA HatTrick⫯ and PBA Seamer⫯
- Ascochyta caused yield losses from 100% to nil depending on when the disease occurred, and the variety grown
- Highest gross margin (GM)'s (> $800/ha) occurred with the lowest incidence of Ascochyta and also with the least susceptible variety, i.e. PBA Seamer⫯
- Manage Ascochyta early and grow varieties with best resistance to minimise impact of Ascochyta
- Follow current Ascochyta advice to maximise enduring profitability.

Why did we do this research?

Current management of chickpea Ascochyta in north central/northern NSW and southern QLD is based on results of field trials conducted mostly at Tamworth, grower experiences and feedback from agronomists. The Tamworth experiments have tried to simulate what happens in most farmers crops, i.e. initial infection occurs during the first post emergence rainfall event – accordingly, all the Tamworth experiments have established Ascochyta during that event. But what is the impact if infection occurs at later stages of growth and how does that affect management? The Trangie Agricultural Research Centre provided an opportunity to address that question – the soil and climate are typical of the Macquarie valley, a major chickpea production region. Overhead irrigation (lateral) and inoculation with conidia and infected spreader plants optimised infection and disease development.

Experiment details

Treatments

Aim: to assess the impact of Ascochyta blight (AB) disease occurring at three different growth stages, on yield of three chickpea varieties with different levels of AB resistance.

Ascochyta treatments (5):

1. **LOW (NIL)**: un-inoculated (NIL disease = CONTROL) plus foliar chlorothalonil fungicide (1.0 L/ha, chlorothalonil 720g/L) applied before rain or irrigation events
2. **HIGH**: inoculated with disease twice (at seedling (SDG, 3-4 nodes) and vegetative (VEG, 7-8 nodes) growth stages); NIL fungicide applied

3. **SDG**: inoculate with disease at seedling stage (3-4 nodes), allow disease to progress for 2-3 rain events to 7-8 nodes, then control disease for rest of season with chlorothalonil
4. **VEG**: protect plants from emergence to vegetative stage (7-8 nodes) with chlorothalonil; inoculate with disease and allow to progress for 2-3 rain events to first pods, then control disease with chlorothalonil
5. **POD**: protect plants from emergence to reproductive stage (first pods) with chlorothalonil, inoculate with disease and allow disease to progress through to harvest.

Variety treatments (3, and level of AB resistance):

1. **Kyabra**⦷ VS = Very susceptible
2. **PBA HatTrick**⦷ MS = Moderately susceptible
3. **PBA Seamer**⦷ MR = Moderately resistant

Replication: 4 reps

Method

The experiment was conducted at Trangie Agricultural Research Centre in central west NSW, on a grey vertosol soil with access to overhead (lateral) irrigation. The experiment was sown as a randomised block design using a small plot seeder, with each plot 2m x 10m. Buffer plots were sown (with PBA Seamer⦷) at the same plot size between each treatment plot, to reduce the impact of inter-plot interference from Ascochyta inoculation and fungicide application. A back-pack sprayer with a 2m wide hand-held wand and 015 110 degree flat fan nozzles @ 50cm, was used to apply both Ascochyta inoculum and fungicide. Buffer plots received the full set of six fungicide applications.

Ascochyta disease was generated in treatment plots by a combination of two inoculation methods:
1. Ascochyta applied to whole plot as conidial suspension (600,000 conidia/mL), and
2. Ascochyta infected spreader plants transplanted to centre of plot.

Ascochyta treatments for each growth stage were applied just prior to either a forecast rain event, or irrigation.

Ascochyta treatment and fungicide were applied as follows:

up to 1 July	NIL fungicides applied prior to first disease treatment
1 July	**inoculation 1 - SDG & HGH treatments (pre-irrigation)**
9 July	fungicide 1 pre-rain - applied to LOW, VEG & POD (not SDG or HGH)
5 August	**inoculation 2 - VEG & HGH treatments (pre-rain)**
13 August	fungicide 2 pre-rain – applied to LOW, SDG & POD (not VEG or HGH)
9 September	fungicide 3 pre-rain – applied to LOW, SDG & POD (not VEG or HGH)
19 September	**inoculation 3 - POD treatment (pre-rain)**
29 September	fungicide 4 pre-rain – applied to LOW, SDG & VEG plots (not POD or HGH)
7 October	fungicide 5 pre-rain – applied to LOW, SDG & VEG plots (not POD or HGH)
21 October	fungicide 6 pre-rain – applied to LOW, SDG & VEG plots (not POD or HGH)

Site details & agronomy management

Sowing date: 26 May 2020
Harvest date: 27 November 2020
Seed treatment:

PBA Seamer⦷ pre-treated with thiram at purchase
Kyabra⦷ & PBA HatTrick⦷ treated with P-Pickel T® pre-sowing

Fertiliser at sowing: Granulock® Z @ 80 kg/ha
Inoculant: Group N, liquid inject at sowing
Target plant density: 30 plants/m^2
Actual establishment achieved:
Kyabra⫙ & PBA Seamer⫙ = 31 plants/m^2 (new seed)
PBA HatTrick⫙ = 21 plants/m^2 (retained seed ex 2019 harvest, poor storage conditions)
Buffers between treatment plots: PBA Seamer⫙ at 30 plants/m^2

Herbicide management:
pre-sow: TriflurX® (trifluralin 480 g/L) @ 1.7 L/ha
PSPE: Terbyne® Xtreme® (terbuthylazine 875 g/kg) @ 0.86 kg/ha
in-crop: haloxyfop 520 @ 100 mL/ha + clethodim 240 @ 250 mL/ha
Fungicide application:
up to 6 chlorothalonil 720g/L @ 1.0 L/ha for LOW (NIL disease) treatment; total number of applications varied for each growth stage treatment
Insecticide & mouse management:
17 Sept Affirm® (emamectin) insecticide @ 300 mL/ha (by plane)
6 Oct Altacor® (chlorantraniliprole) insecticide @ 70 g/ha (by plane)
12 Oct Zinc phosphide mouse bait @ 1.0 kg/ha (by plane)
Harvest management:
desiccation not required due to heatwave conditions from 15 November on
experiment harvested at 9% moisture content.
Pre-sowing rainfall (1/01/20 to 25/05/20): 351 mm
In-crop rainfall (26/05/20 to 27/11/20): 201 mm in 49 events
Plus in-crop irrigations: 20 mm (as 2 x 10 mm events)

Table 1. Summary of dates of disease inoculations and fungicide applications for 2020 Trangie chickpea Ascochyta management trial, relative to dates of subsequent rain or irrigation events.

2020 date	Disease inoculation	Fungicide application	Rain > 2.0mm	Irrigation (mm)	Cumulative >2.0mm # Events	Cumulative >2.0mm (mm)
01 Jul	SDG & HIGH		0.0	10.0	1	10.0
09 Jul		LOW, VEG & POD				
10-13 Jul			31.6		2	41.6
25-27 Jul			35.8		3	77.4
05 Aug	VEG & HIGH					
06-12 Aug			19.2		4	96.6
13 Aug		LOW, SDG & POD				
14-22 Aug			18.8		5	115.4
09 Sep		LOW, SDG & POD	3.8		6	119.2
14 Sep			0.0	10.0	7	129.2
19 Sep	POD					
19-25 Sep			33.8		8	163.0
29 Sep		LOW, SDG & VEG				
7 Oct		LOW, SDG & VEG	6.8		9	169.8
17 Oct			3.4		10	173.2
21 Oct		LOW, SDG & VEG				
23-25 Oct			17.6		11	190.8
4-5 Nov			7.8		12	198.6

Table 2. Log of operations for 2020 Trangie experiment on managing chickpea Ascochyta when disease occurs at different growth stages: Inoc = inoculation, DAS = days after sowing, DAI = days after inoculation.

	Ascochyta treatment			
Operation	**HIGH**	**SDG**	**VEG**	**POD**
Sow date	26/05/2020	26/05/2020	26/05/2020	26/05/2020
1st Inoc date	1/07/2020	1/07/2020	5/08/2020	19/09/2020
2nd Inoc date	5/08/2020	not done	not done	not done
1st Inoc DAS	36	36	71	116
2nd Inoc DAS	71	not done	not done	not done
Score 1 date	26/08/2020	26/08/2020	26/08/2020	26/08/2020
Score 2 date	1/10/2020	1/10/2020	1/10/2020	1/10/2020
Score 3 date	14/10/2020	14/10/2020	14/10/2020	14/10/2020
Score 1 DAI	56	56	21	na
Score 2 DAI	92	92	57	12
Score 3 DAI	105	105	70	25

Results

The effects of Ascochyta treatment, Variety and Ascochyta x Variety were highly significant (P<0.001) for all variables measured.

Disease incidence

The seedling, (SDG) and HIGH Ascochyta treatments were inoculated on 1 Jul 20, 36 days after sowing, DAS (Table 2). The HIGH treatment was inoculated a second time on 5 Aug (71 DAS) to maximise disease development (Table 2). This resulted in severe early disease (assessed on 26 Aug) in Kyabra⑮, moderate disease in PBA HatTrick⑮ and demonstrated the improved Ascochyta resistance in PBA Seamer⑮ (Table 3). The vegetative, VEG treatment was inoculated on 5 Aug (71 DAS), prior to which plants had been protected with foliar fungicide applied on 9 Jul. This regime produced low disease in Kyabra⑮and PBA HatTrick⑮ at the 1st and 2nd assessments (26 Aug, 1 Oct) and nil in PBA Seamer⑮ (Table 3). The podding, POD treatment was inoculated on 19 Sep (116 DAS), prior to which plants had been protected with foliar fungicides applied on 9 Jul, 13 Aug and 9 Sep. This regime produced nil disease in all three varieties at the 1st assessment (26 Aug) and low disease at the two subsequent assessments (1 Oct, 14 Oct) (Table 3). We assign the low incidence of Ascochyta with the POD treatment as a consequence of the three fungicide sprays applied before inoculation and less favourable seasonal conditions.

Table 3. Incidence of Ascochyta (% plot with disease) in Kyabraⓓ, PBA HatTrickⓓ and PBA Seamerⓓ chickpeas when disease was established at different growth stages but controlled before and after; l.s.d. (*P*=0.05) for Scores 1, 2 & 3 = 13.26%, 8.63% & 11.74%, respectively.

Variety	Ascochyta treatment	Score 1 26 Aug 20	Score 2 01 Oct 20	Score 3 14 Oct 20
Kyabra ⓓ	LOW	1.3	0.0	5.2
PBA HatTrick ⓓ	LOW	0.0	0.0	11.2
PBA Seamer ⓓ	LOW	0.0	0.0	3.0
Kyabra ⓓ	SDG	92.0	57.5	70.0
PBA HatTrick ⓓ	SDG	37.5	22.5	40.0
PBA Seamerⓓ	SDG	0.0	0.0	2.8
Kyabra ⓓ	VEG	8.8	12.5	31.2
PBA HatTrick ⓓ	VEG	5.0	8.8	22.5
PBA Seamerⓓ	VEG	0.0	0.0	3.0
Kyabra ⓓ	POD	0.0	0.5	7.8
PBA HatTrick ⓓ	POD	0.0	2.5	5.2
PBA Seamerⓓ	POD	0.0	0.0	3.8
Kyabraⓓ	HIGH	88.8	100.0	100.0
PBA HatTrick ⓓ	HIGH	32.5	52.5	57.5
PBA Seamer ⓓ	HIGH	0.0	0.0	4.0

This approach, i.e. inoculating Ascochyta at different times and protecting before and after, allowed us to determine the impact of disease at those stages on yield.

Impact on yield

Table 4. Effect of Ascochyta on grain yield, gross margin (GM) and yield loss for three chickpea varieties when disease occurs at different growth stages; l.s.d. (*P*=0.05) yield 286 kg/ha. GM is based on chickpea price of $600/t, fungicide product $16/ha/application, fungicide ground rig application $5/ha, other production costs $300/ha.

Variety	Ascochyta Treatment	Yield (kg/ha)	GM ($/ha)	% Yield Loss (kg/ha)
Kyabra ⓓ	LOW	1878	701	0
PBA HatTrick ⓓ	LOW	1840	678	0
PBA Seamer ⓓ	LOW	2138	857	0
Kyabra ⓓ	SDG	10	-399	99
PBA HatTrick ⓓ	SDG	965	174	48
PBA Seamerⓓ	SDG	2080	843	3
Kyabra ⓓ	VEG	1483	506	21
PBA HatTrick ⓓ	VEG	1504	518	18
PBA Seamer ⓓ	VEG	2211	943	-3
Kyabra ⓓ	POD	2041	862	-9
PBA HatTrick ⓓ	POD	1880	765	-2
PBA Seamer ⓓ	POD	2101	898	2
Kyabra ⓓ	HIGH	0	-300	100
PBA HatTrick ⓓ	HIGH	234	-160	87
PBA Seamer ⓓ	HIGH	1903	842	11

Grain yield (Table 4) ranged from nil (Kyabra⏀ HIGH) to over 2 t/ha (all PBA Seamer⏀ treatments). For the very susceptible Kyabra⏀, lowest yields occurred with the SDG and HIGH treatments with yield losses of 99% and 100% respectively. The moderately susceptible PBA HatTrick⏀ also had lowest yields for SDG and HIGH treatments, with losses of 48% and 87% respectively (Table 4). The least susceptible variety PBA Seamer⏀ only lost 3% and 11% yield from SDG and HIGH treatments.

Gross Margins, GM

The highest GM's occurred with the lowest incidence of Ascochyta (LOW) and also with the least susceptible variety PBA Seamer⏀ (Table 4). All PBA Seamer⏀ treatments, including the one with most Ascochyta, (HIGH) had GM over $800/ha (Table 4). However, the experiment showed that controlling Ascochyta in the very susceptible Kyabra⏀ is profitable with a GM of $701/ha and $862/ha for the LOW and POD treatments respectively.

Conclusions

Generating chickpea Ascochyta at different stages of growth showed when and how disease affects yield. The impact of disease on a chickpea crop depends primarily on when the disease occurs, how it is managed, and the variety grown. Allowing Ascochyta to establish early in the life of your crop results in greatest impact on yield and lowest profitability, even if the disease is subsequently controlled with foliar fungicides. This is especially true for very susceptible and moderately susceptible varieties. Your best option for minimising impact of Ascochyta on chickpea production and maximising profitability is to follow current recommendations (Moore and Heuston, 2020) by controlling disease early and growing the least susceptible variety. This approach will also reduce the build-up and carryover of Ascochyta inoculum for your and your neighbour's future chickpea crops.

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Contact details

Leigh Jenkins & Kevin Moore
NSW DPI, Trangie Agricultural Research Centre & Tamworth Agricultural Institute
Ph: LJ 0419 277 480, KM 0488 251 866
Email: leigh.jenkins@dpi.nsw.gov.au, kevin.moore@dpi.nsw.gov.au

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Viral diseases in faba bean, chickpeas, lentil and lupins. Impacts, vectors/causes and management strategies for 2021

Joop van Leur and Zorica Duric, NSW DPI

Key words

faba bean viruses, *Bean yellow mosaic virus*, *Alfalfa mosaic* virus, aphids

GRDC codes

DAN00202, DAN00213/BLG209, DAN00213/BLG204

Take home messages

- The severe virus epidemic in faba bean in northern NSW during 2020 was initiated by early and massive flights of aphids (mainly cowpea aphids) that carried *Bean yellow mosaic virus* (BYMV) into the crops
- After a 2-year drought, heavy January and February rains in north-west NSW triggered the emergence of naturalised medics and other pasture legumes, which allowed a build-up of aphids and virus prior to the emergence of faba bean crops
- Most faba bean crops were sown into bare ground as cereal stubble was lacking after the extended drought. Lack of standing cereal stubble or uneven emergence makes pulse crops particularly vulnerable to early aphid infections
- Relatively mild and dry conditions during the start of the season favoured aphid multiplication in the faba bean crops and a fast spread of virus from initial infection foci
- Co-infections of BYMV and *Alfalfa mosaic virus* (AMV) caused particularly severe symptoms in several crops
- Both BYMV and AMV are non-persistently transmitted viruses that require only a short probing period by a viruliferous aphid to infect a plant. Slow-acting insecticides like imidacloprid applied to seed will not prevent infection of non-persistently transmitted viruses by incoming, winged, aphids . However, they may help in slowing the multiplication of aphids in the crop and subsequent spread of the virus by wingless aphids
- Further work is needed to investigate how long an imidacloprid seed dressing remains active and whether a foliar application of a pulse registered product (pirimicarb) after aphids are found in a crop is more practical, economic or effective
- There are no indications that transmission of BYMV to faba bean seed occurs at significant levels
- Virus control strategies are all based on preventing infection, particularly during the early growth stages of the crop. Poorly emerging crops or crops sown into bare ground are particularly vulnerable to infection. Sowing in standing cereal stubble and using high quality seed with good seedling vigour has shown to be the most reliable management option to avoid virus infections.

Pulse viruses and pulse virus vectors

Pulses are far more vulnerable to virus infection than winter cereals with over 20 viruses considered to be of economic importance on pulse crops worldwide. All major pulse viruses require an insect vector (mostly an aphid species) to transmit the virus to a healthy plant. The mode of transmission can be non-persistent, which means that the aphid only needs a short probe of the plant in order to acquire or to transmit the virus, while persistently transmitted viruses require a longer feeding period by the aphid. Plants can be infected by most non-persistently transmitted viruses under experimental conditions through rubbing a virus suspension into the leaf ('mechanical inoculation'), while a viruliferous vector is always needed for the persistently transmitted viruses. Viruliferous aphids will lose a non-persistently transmitted virus after probing a healthy plant, but aphids that carry a persistently transmitted virus remain viruliferous.

The difference in the time needed to transmit a virus has implications for the effectiveness of aphicides to control virus infections; infection by a persistently transmitted virus like *Bean leafroll virus* (BLRV) can be prevented by a timely foliar application of an insecticide or by seed dressing with a systemic insecticide, but most aphicides are not fast enough to prevent infection by a non-persistently transmitted virus like *Bean yellow mosaic virus* (BYMV).

Virus epidemiology and the prediction of severe virus epidemics is complicated as aphid numbers and movements depend on numerous factors, both during and preceding the growing season. A few viruses can survive in seed, but most require a 'green bridge' of living host to survive between cropping seasons. Pulse viruses are not host species specific and naturalised pasture legumes, like medics or sub clovers, or perennial legumes, like lucerne or white clover, can be infected with a range of viruses that can be harmful to grain legumes like faba bean or chickpea. Viruses like BYMV and AMV can be seed transmitted in several pasture legume species and viruses and their vectors can build up in pastures, roadside weeds or stock routes prior to the emergence of pulse crops. Also, a virus that can devastate grain legumes might have little or no impact on a pasture legume or a weed; e.g. *Bean leafroll virus* (BLRV) kills pulses like faba bean, field pea, lentil and field pea, but is symptomless on lucerne, its main summer host.

Different aphid species have different temperature optima, but generally mild weather favours aphid multiplication. Aphids can multiply very fast and host plant population can become rapidly overcrowded, particularly if the host plants are still in an early stage of development (as with naturalised pasture legumes during late summer-early autumn). Overcrowding or deterioration of the host plant will trigger the development of winged aphids who can, largely through wind currents, migrate over long distances. Large peaks in movements of winged aphids can be observed during autumn and can be harmful for early sown crops like faba bean and lupins. Aphid activity generally slows down during winter but picks up again with rising temperatures and major aphid flights can be again observed in spring. Later-sown pulse crops like chickpeas generally escape the autumn aphid flights but are vulnerable to the spring flights.

Faba bean viruses in northern NSW

Within Australia 12 viruses have been reported to infect faba bean, but not more than five have caused serious yield reductions in the past (Table 1). Surveys in northern NSW over the last two decades identified *Bean leafroll virus* (BLRV) as the most important faba bean virus. Severe symptoms, like stunting and plant death, were found after infection by BLRV and (less frequently) by the closely related *Soybean dwarf virus* (SbDV). Heavy yield losses by BLRV were recorded in the early 2000's on the highly susceptible cultivar Fiord, particularly in paddocks close to lucerne, the major BLRV summer host. Germplasm screening for resistance was successful in identifying good sources of BLRV resistance, which were used in the breeding program to develop varieties with improved resistance.

In 2004 and 2005 high incidences of the thrips transmitted *Tomato spotted wilt virus* (TSWV) were found in faba bean paddocks north of Moree. The sudden occurrence of TSWV was likely a result of the recent incursion of the western flower thrips (*Frankliniella occidentalis*), a highly effective vector. TSWV has a very wide host range and is lethal on faba bean. However, although infections of up to 10% were found in some crops, infected plants remained randomly scattered through paddocks and, surprisingly, no secondary spread could be noticed. TSWV was rarely found in more recent surveys.

Other viruses that can cause plant death, but only occur sporadically, are *Sub clover stunt virus* (SCSV) and *Clover yellow vein virus* (CYVV).

Table 1. Faba bean viruses in Australia (in alphabetical order)

Virus	Abr.	Transmission	Major vectors	Seed transmission[1]	Occurrence in NSW faba bean crops	Impact on plants
Alfalfa mosaic	AMV	non-persistent	many aphid species	medics, lucerne, lupin	low incidences every year	moderate
Bean leafroll	BLRV	persistent	pea, cowpea aphid	no	very high occasionally	high
Bean yellow mosaic	BYMV	non-persistent	many aphid species	medics, sub clover, (faba bean)	high incidences regularly, normally at end of season	high after early infection
Broad bean wilt	BBWV	non-persistent	green peach aphid and others	no	very rare	high
Cucumber mosaic	CMV	non-persistent	many aphid species	lupin, lentil	very rare	low
Clover yellow vein	CYVV	non-persistent	cowpea aphid	no	rare	high
Pea seed-borne mosaic	PSbMV	non-persistent	many aphid species	field pea, (lentil)	rare	low
Phasey bean mild yellows	PBMYV	persistent	cowpea aphid	no	?	?
Sub clover stunt	SCSV	persistent	cowpea aphid	no	generally rare, widespread occasionally	high
Soybean dwarf	SbDV	persistent	pea aphid and others	no	low incidences regularly	high
Turnip yellows[2]	TuYV	persistent	green peach aphid	no	high incidences regularly at end of the season	moderate
Tomato spotted wilt	TSWV	persistent	Western flower thrips and other thrips	no	occasionally low incidences	high

[1] Seed transmission of host species listed between brackets is reported, but unlikely to be of significance
[2] TuYV was previously known as *Beet western yellows virus* (BWYV)

While survey results indicated that BLRV was the most important virus because of its impact on yield, BYMV was always the most frequently identified virus throughout northern NSW. Generally, infections appeared late in the season and symptoms consisted only of a relatively mild mosaic in the top leaves above the pod setting nodes and no serious impact on yield was noticeable in commercial crops. However, yield loss trials comparing BYMV inoculated with non-inoculated plots (using mechanical inoculation at the 3-4 leaf stage) demonstrated that early infections could have a major impact on yield with over 50% yield reduction on PBA Warda⦶ and PBA Nasma⦶ (the two most common varieties in northern NSW) and close to 70% yield reduction on the highly susceptible southern variety Fiesta VF. Large numbers of breeding lines and germplasm accessions were evaluated in BYMV inoculated screening trials over the years, but no lines with high levels of resistance were identified. Unlike with BLRV, no plant death was observed in the yield loss or resistance screening trials, except for several germplasm accessions from Ecuadorian origin that showed hyper-sensitive reactions.

The 2020 faba bean virus epidemic in northern NSW

By early June 2020 serious symptoms in early sown faba bean crops were reported in several sites in northern NSW. Patches of necrotic and stunted plants in the affected paddocks resembled severe early infections by BLRV, SCSV or TSWV seen in earlier years. However, testing of symptomatic plants by Tissue Blot Immunoassay (TBIA) at the Tamworth Agricultural Institute (TAI) and by molecular tests at the QDAF virology laboratory in Brisbane (Dr Murray Sharman) showed the main virus to be BYMV, with co-infection by AMV in some paddocks (Table 2).

Table 2. Presence of three major faba bean viruses and one virus group in collected and submitted faba bean samples, northern NSW, 2020 [1]

Symptom type	Tested plants	% positive plants as determined by TBIA			
		BYMV	AMV	BLRV	Luteovirus[2]
Randomly collected	359	44.3	13.1	1.1	7.5
No symptoms	407	49.9	6.4	0.2	2.0
Not specified virus symptoms	279	58.4	15.4	2.5	9.0
Plant necrosis	329	81.8	26.4	0.3	2.4
Plant stunting	194	66.0	5.2	12.9	7.2
Leaf mosaic	234	88.9	11.5	0.0	3.8
Total plants tested	1802	62.7	13.3	2.1	5.0

[1] Minor incidences found for SCSV (7 plants out of 325 tested), CYVV (1 plant out of 991 tested) and *Cucumber mosaic virus* (CMV, 4 plants out of 682 tested)
[2] Luteoviruses other than BLRV

The early infections followed high populations of migrating aphids observed on aphid traps during autumn 2020 (Figure 1). The main aphid species found on the traps was cowpea aphid (*Aphis craccivora*), but other aphid species known to colonise pulse species were also found in high numbers: pea aphid (*Acyrthosiphon pisum*), blue-green aphid (*Acyrthosiphon pisum*) and green-peach aphid (*Myzus persicae*). Cowpea aphid is a highly effective vector of both persistently and non-persistently transmitted viruses, and - equally important - it colonises and multiplies on faba bean. Further surveys and testing during the season showed clear foci spreading from early infected plants, a pattern typical of colonising, wingless aphids.

Several agronomists expressed concern that green mirids (*Creontiades dilutes*), which were in abundance in faba bean crops during 2020, were capable of transmitting BYMV. We have undertaken two separate trials in which green mirids were left for 24 hours on BYMV infected faba bean plants in insect proof tents, before healthy faba bean plants were placed in the same tent. No

BYMV transmission from the infected to the healthy plants was observed, confirming numerous publications that only aphids can transmit this virus.

As the season progressed the virus spread through most faba bean paddocks in northern NSW, but severe symptoms generally remained restricted to early infected paddocks. Large differences in severity could be observed between paddocks that were at close distance, and paddocks close to the Queensland border and those south of Gilgandra were less affected (Figure 2). Virologists from QDAF confirmed the presence of BYMV in faba bean paddocks in Queensland, but severe symptoms were rare except for an irrigated crop near St George.

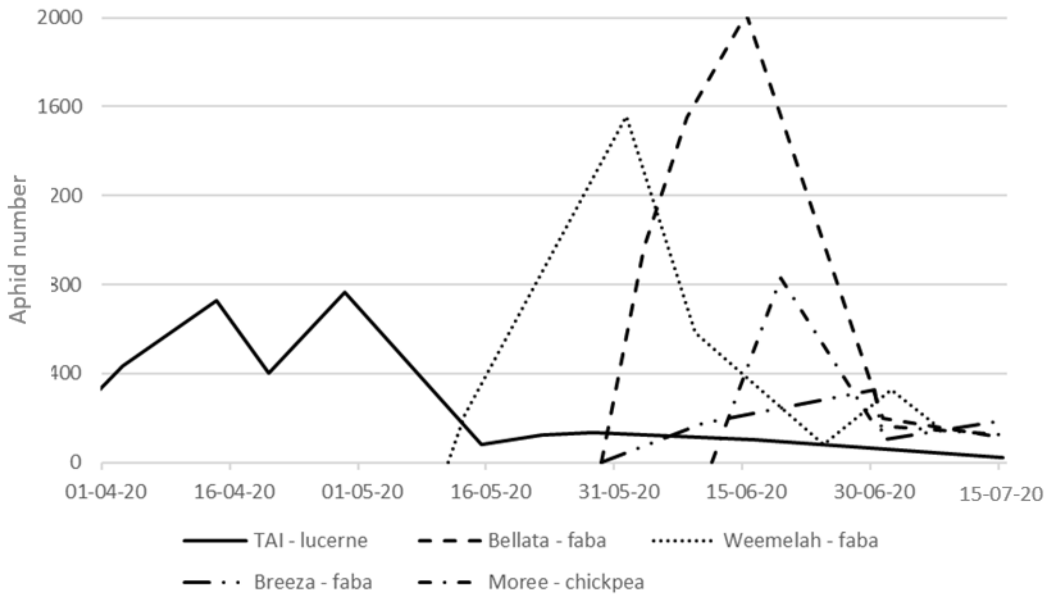

Figure 1. Aphids (number of aphids / m^2 yellow sticky trap / day) caught on yellow sticky traps in 5 sites in northern NSW, Autumn 2020

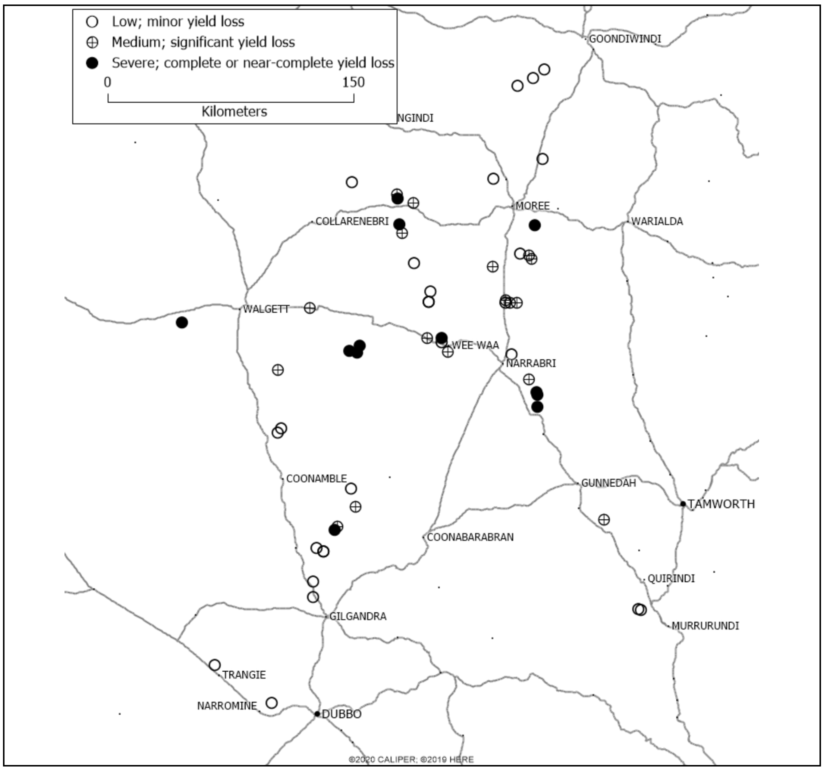

Figure 2. Severity of virus infections in 55 faba bean paddocks Northern NSW, 2020

The very high early aphid numbers and severe virus in north-western NSW points to a possible role of naturalised pasture legumes in the epidemiology of pulse viruses: After two very dry years, the January - February rains in the north-western part of the state would have triggered the emergence of large areas of medics and other potential virus hosts. Mild temperatures promoted a fast multiplication of aphids and when aphid populations on the medics became too crowded, winged aphids would have moved to newly emerged faba bean crops. BYMV (and AMV) are both transmitted in medic seed, so even with low seed transmission rates enough aphids could have picked up inoculum to establish infection foci in faba bean crops. Continuing mild temperatures during the start of the season allowed multiplication of aphids in the faba bean crops and spread of the virus from the initial infection foci. The preceding drought also had indirect effects on the high level of virus infections: Aphids tend to avoid crops sown in standing cereal stubble and with less cereal crops grown in 2019, more faba bean crops were sown into bare ground. Also, faba bean seed was in short supply and some seed used was rather old and less vigorous.

While the unusual severity of BYMV infection during 2020 was likely a direct result of very early infections and, in some cases, co-infection by AMV, it is also possible that more virulent BYMV strains were present. BYMV is known to be variable in pathogenicity and host species specificity. We have isolated a large number of strains this year and are in the process of evaluating these using pathogenicity testing and molecular tools.

Viruses in crops other than faba bean

Virus symptoms were observed in several chickpea crops in the Moree-Narrabri region that were bordering faba bean paddocks. The level of infection was high close to the border but diminished rapidly further from the faba bean crop. Testing of virus symptomatic plants showed that while the faba bean paddocks had high BYMV and minor AMV infection levels, symptomatic chickpeas were only infected by AMV. BYMV is reported to be capable of infecting chickpeas, but in our greenhouse tests chickpeas reacted as immune to the majority of BYMV strains isolated from faba bean.

Random samples taken from chickpea paddocks by Dr Kevin Moore as part of his yearly disease survey (Table 3), showed that the later sown chickpea crops generally escaped the aphid autumn flights. The absence of virus spread in chickpea paddocks also demonstrated that aphids rarely colonise chickpeas and infection is generally caused by incoming, winged aphids.

Table 3. Presence of four major pulse viruses and one virus group in collected and submitted samples of pulses (other than faba bean), NSW, 2020.

Species	Tested plants	% positive plants as determined by TBIA				
		BYMV	AMV	BLRV	Luteovirus[1)]	CMV
Chickpeas	1,329	0.0	5.5	0.3	1.1	1.1
Lentils	1,161	0.2	12.7	2.7	0.3	34.6
Lupins	227	1.3	28.6	0.9	0.0	90.3

[1] Luteoviruses other than BLRV

Both lupins and lentils are, unlike chickpeas, crops colonised by several aphid species and highly vulnerable to infection by a range of viruses. CMV caused severe symptoms in narrow-leafed lupin crops in the Gilgandra region with co-infection by AMV aggravating losses in several paddocks. CMV can be seed-transmitted in narrow-leafed lupins at high rates and testing of several seed lots that were used for the 2020 sowing showed dangerously high CMV levels. Narrow-leafed lupins in NSW are generally used as stockfeed on farm and most growers multiply their own seed stock for several years. While virus infections might remain unnoticed in most years, seed infection levels can build up slowly and cause a severe virus epidemic in an aphid favourable season like 2020.

Lentils are still an experimental crop in most of NSW, but the high levels of CMV and other viruses in lentil samples taken from trial sites (Table 3) showed that viruses may become a major factor limiting the expansion of lentils.

Virus control strategies

Virus control strategies will differ between crops and virus species, but all are aimed at avoiding infection as curative control of viruses is not possible.

Minimising numbers of incoming virus vectors

The most effective strategy currently is to minimise virus infection by promoting fast canopy closure through following optimal agronomic practices and use of high quality seed with good seedling vigour. Migrating aphids prefer landing in crops that show uneven emergence and bare ground, while sowing in standing stubble deters aphid landings. Early sowing increases the risk of virus infection as crops are exposed to the autumn aphid flights when plants are small and most vulnerable to virus infection. However, later sowing is often not a practical option for growers.

Virus-free seed

Several non-persistently transmitted viruses can be seed-borne in pulses. Sowing virus-infected seed will result in infection foci scattered randomly throughout a crop right after crop emergence and a rapid spread of the virus. Fortunately, for most virus / pulse host combinations, the levels of seed transmission are very low and, while still very important for quarantine, not of concern in commercial crops. The exceptions are CMV in narrow-leafed lupins and lentils and *Pea seed-borne mosaic virus* (PSbMV) in field peas. Growers who keep their own seed should have it tested and only use virus-free seed.

BYMV can be seed-transmitted in faba bean, but so far we haven't found any evidence of its presence in commercial or farmers' seed lots. However, new virus strains can develop that have a better ability to be seed transmitted, so our testing program is continuing.

Avoiding inoculum sources

Unlike most fungal pathogens, viruses don't survive in stubble or soil. Apart from those that are seed-transmitted all will be brought into the crop by vectors from outside sources. It is advisable to keep distance from known sources of infection like lucerne. Weed and volunteer legume crops within or near crops are also key virus sources and should be controlled before the crop emerges.

Chemical control of vectors

The effectiveness of aphicides to control virus infection differs between viruses. Viruses that are persistently transmitted, like BLRV or TuYV, require a relatively long feeding period and a seed treatment with a systemic insecticide can provide protection during early growth when plants are most vulnerable. Non-persistently transmitted viruses, like BYMV, CMV or AMV, only require a brief probing to transmit virus and the insecticides used for seed treatment act too slowly to prevent infection.

Imidacloprid is registered as a seed treatment for early aphid control on faba bean, field pea and lentils. The seed treatment will not stop initial BYMV infections from migrating aphids, but it could possibly delay the build-up of colonising aphids in a crop and thereby limit virus spread. Greenhouse trials in 2020 confirmed that imidacloprid seed treatment reduced the multiplication of cowpea and pea aphid numbers on faba bean, but it took more than one day to kill aphids. Field research is needed to determine how long an imidacloprid seed treatment remains effective and whether it will be more useful than a well-timed foliar aphicide application.

Resistance

Genetic resistance can be a very economical and environmentally friendly option for virus control. Over the years good resistance has been identified for several pulse / virus combinations and subsequently used in Australian pulse breeding programs.

Unfortunately, the search for high levels of BYMV resistance in faba bean has not been successful so far. There are differences among Australian faba bean varieties in symptom expression with some of the older varieties and lines developed for the southern region reacting as 'very susceptible'. There were no indications that the current northern region varieties differed in their BYMV reaction during the 2020 epidemic, but a few breeding lines yielded well in different sites under severe BYMV pressure. These lines will be tested during the 2021 season in inoculated trials.

All narrow-leafed lupin varieties are CMV susceptible, but a number of varieties are moderately resistant to CMV seed infection. While these varieties are still susceptible to CMV by aphid transmission, the build-up of inoculum in seed stock will be slower and the risk on CMV induced losses during virus favourable seasons will be lower.

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There is a wealth of information on pulse viruses published on the internet by the agricultural departments of Western Australia (https://www.agric.wa.gov.au/), Queensland (https://www.daf.qld.gov.au/), Victoria (https://agriculture.vic.gov.au/) and New South Wales (https://www.dpi.nsw.gov.au/).

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Contact details

Joop van Leur
NSW Department of Primary Industries
4 Marsden Park Rd, Tamworth, 2340, NSW
Ph: 0427 928 018
Email: joop.vanleur@dpi.nsw.gov.au

Zorica Duric
NSW Department of Primary Industries
4 Marsden Park Rd, Tamworth, 2340, NSW
Ph: 02 6763 1154
Email: zorica.duric@dpi.nsw.gov.au

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Identification of crop –specific and varietal tolerance limits to acidity, salinity and sodicity

Jack Christopher[1], Kathryn Page[2], Yash Dang[2] and Neal Menzies[2, 1]

[1] *Queensland Alliance for Agricultural and Food Innovation, The University of Queensland*
[2] *School of Agriculture and Food Sciences, The University of Queensland*

Key words

soil constraints, chloride toxicity, variety selection, proxy traits

GRDC codes

UA000159: Improving wheat yields on sodic, magnesic and dispersive soils

UOQ1803-003RTX: Economics of ameliorating soil constraints in the northern region: Spatial soil constraint diagnoses

Take home messages

- In Qld and NSW, the soil constraints affecting the greatest cropping areas are sodicity combined with toxic chloride (Cl) concentrations. Acid sub-soils are also important in some areas
- Reduced ability to extract soil water from deeper layers is the main affect reducing yield
- Crop-specific tolerance limits vary between species and between soil constraints
- Tolerance to soil constraints differs between varieties of wheat
- Robust ranking would allow growers and breeders to select the most tolerant varieties, but high spatial soil variation over short distances makes consistent ranking difficult
- We are testing whether pre-screening for proxy traits in the laboratory and using remote sensing to account for spatial variation in the field can be used to increase our ability to select the most tolerant varieties.

Introduction

Successful dryland crop production in the north-eastern Australia depends on utilising soil moisture accumulated in the period preceding sowing. Due to the high clay content of the soils in the region, these soils can potentially store 200-250 mm of water in the soil profile or more. However, soil constraints, especially in the subsoil, reduce the effective rooting depth thus also reducing the amount of water and nutrients that plants can obtain from the soil, resulting in reduced crop yield (e.g. Figure 1) (Dang et al. 2006 and 2016).

High sodicity in surface soil and subsoil, high salinity and phytotoxic concentration of chloride (Cl) in the subsoil, alkalinity, subsoil acidity and compaction are common soil constraints in many semi-arid regions worldwide and in particular Queensland and NSW (Figure 2, Table 1). These soil constraints often occur in combination and can interact with each other to create unique environments for root growth at a given location (Nuttall et al. 2003). They may also vary both spatially and temporally. Spatial variation can occur within a field, across the landscape and with depth in the soil profile.

Spatial variability and the interactions between constraints can limit agronomic and management options. Variability in the impact on crop growth and yield is also compounded by the interaction between constraints and environmental factors, particularly the timing and amount of rainfall relative to the crop development cycle.

The amelioration of soils affected by constraints is usually expensive, if it is possible at all. The application of ameliorants (e.g. gypsum for sodicity) can sometimes improve surface soils (Page et al

2020, 2021). However, amelioration of constraints occurring in the subsoil is not usually practical. Where subsoil constraints are present, the selection of crops or varieties tolerant to soil constraints and the identification of traits for pre-selection may provide a long-lasting, tangible solution to improve yields.

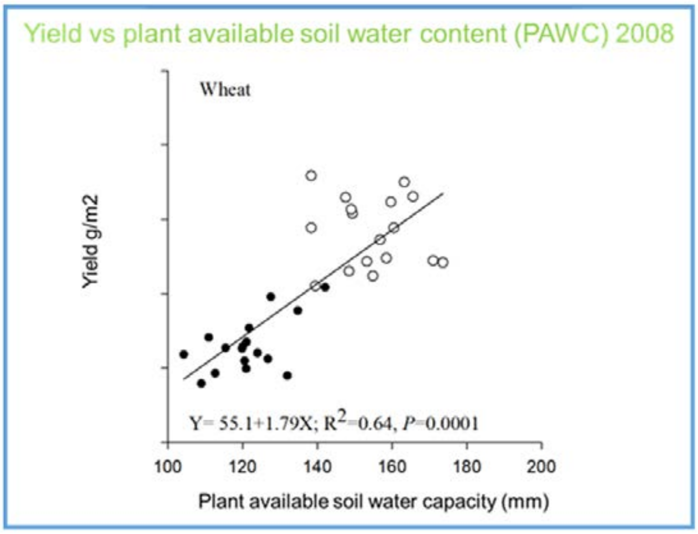

Figure 1. Wheat yield versus soil water extracted between sowing and maturity (plant available soil water capacity, Dang et al., 2016). Solid dots represent data for a highly sodic site and open dots a less-sodic site.

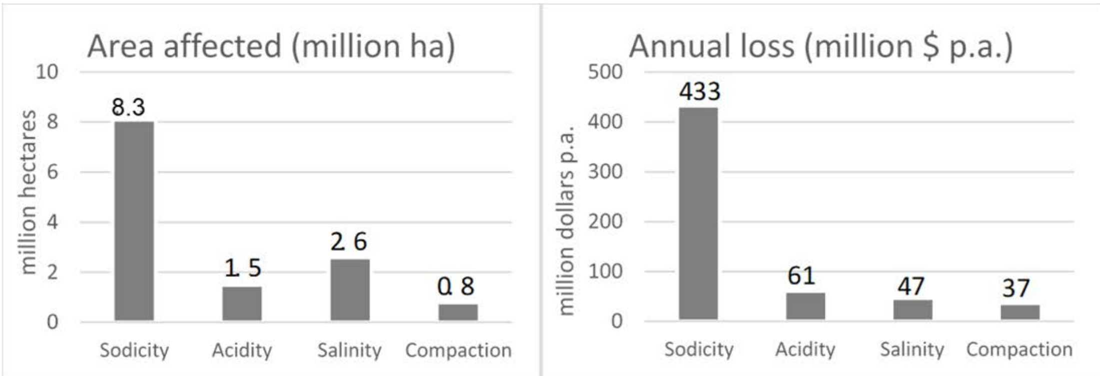

Figure 2. Area affected and annual financial loss due various soil constraints in Queensland and NSW (Orton et al. 2018)

Table 1. Sodicity combined with high chloride concentration at depth represent the main soil constraints in QLD and NSW (Orton et al. 2018).

Region	**Area of cropping land affected (million ha)**		**Estimated cost in lost production**
	Sodicity	Subsoil Cl	(million $/yr)
Central Qld	1.4	0.7	59.5
Southern Qld	1.4	0.9	85.4
Northern Qld	3.0	1.0	157.0
Central NSW	1.3	<0.1	54.3
Southern NSW	1.0	<0.1	77.0
Total	**8.1**	**2.7**	**433.1**

Crop-specific tolerance limits vary between species and between constraints

Saline soils

Soil salinity refers to the amount of salt dissolved in the soil solution and is quantified by measuring the electrical conductivity of a saturated soil extract (ECe). Lower ECe values are generally more favourable for crop production.

A recent survey of published studies on the tolerance of 17 crop species reported that the tolerance thresholds for soil constraints varied between species and between constraints (Page et al., 2021). The tolerance levels of different crops for soil salinity were classified using a 'traffic light' system (Figure 3). Salinity levels for which little if any reduction in yield was reported in the literature were classified green. Levels where some yield loss might be observed (depending on soil type, season and variety) are represented in yellow, while those where loss was reported for most soils, seasons and varieties are represented in red. For example, the studies indicate that the more tolerant cereals, such as barley and millet, will typically perform well up to salinity levels of ECe 5 ds/m. However, they usually suffer severe damage at levels above ECe 10 ds/m (Figure 3). In contrast, more sensitive cereals, such as maize and sorghum, only performed well up ECe 2 ds/m and suffered severe damage at levels greater than ECe 5 ds/m. Some legume species were even more sensitive (Figure 3).

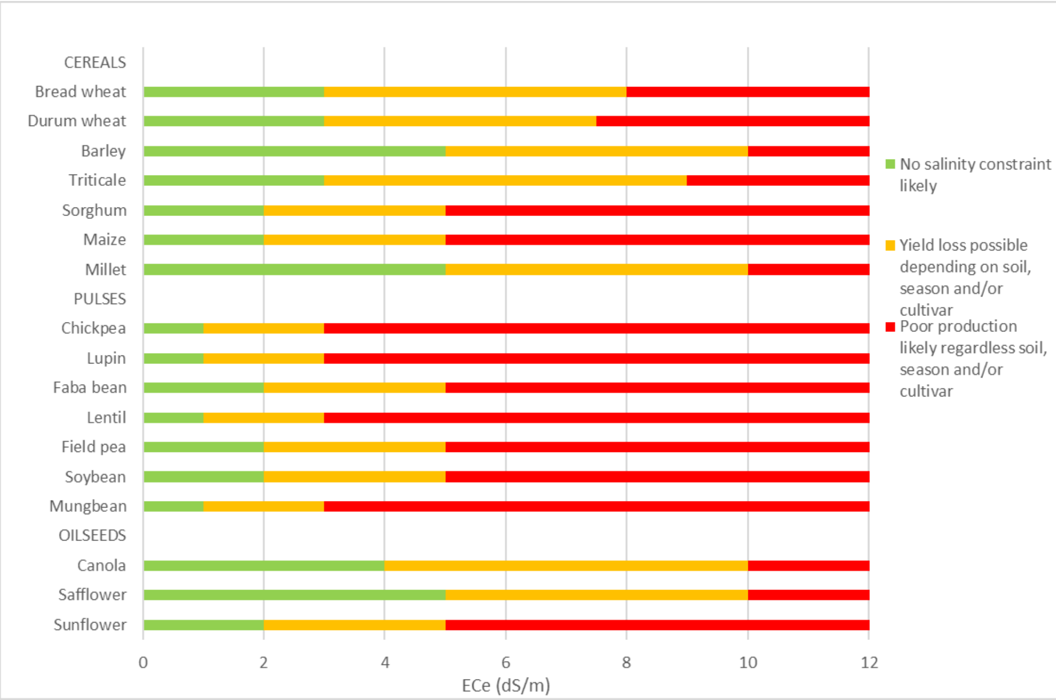

Figure 3. Soil EC_e tolerance limits proposed for crop species when grown under rainfed conditions in subtropical regions (Page et al., 2021).

Acid soils

The adverse effects of soil acidity generally increase with lower pH values measured in the soil solution.

Just as for salinity, the tolerance thresholds of crops varied between the 17 species and between constraints (Page et al., 2021). However, the ranking of the crops was very different. Results are represented here in Figure 4, again using the 'traffic light' system described above. For acidity, the cereals sorghum, maize and millet were able to tolerate more severe acidity levels than many other species, with good growth to as low as pH 5.5 and severe yield loss once pH dropped below pH 4.8.

In contrast, the most sensitive cereals were durum and barley, which performed well only down to pH 6.0 and suffered severe yield loss below pH 5.3. Some legume species were also similarly sensitive (Figure 4).

Thus, the crop species most suitable for a particular paddock can vary greatly depending on which are the most prevalent soil constraints. Crop and cultivar choice are also affected by the season and the variety.

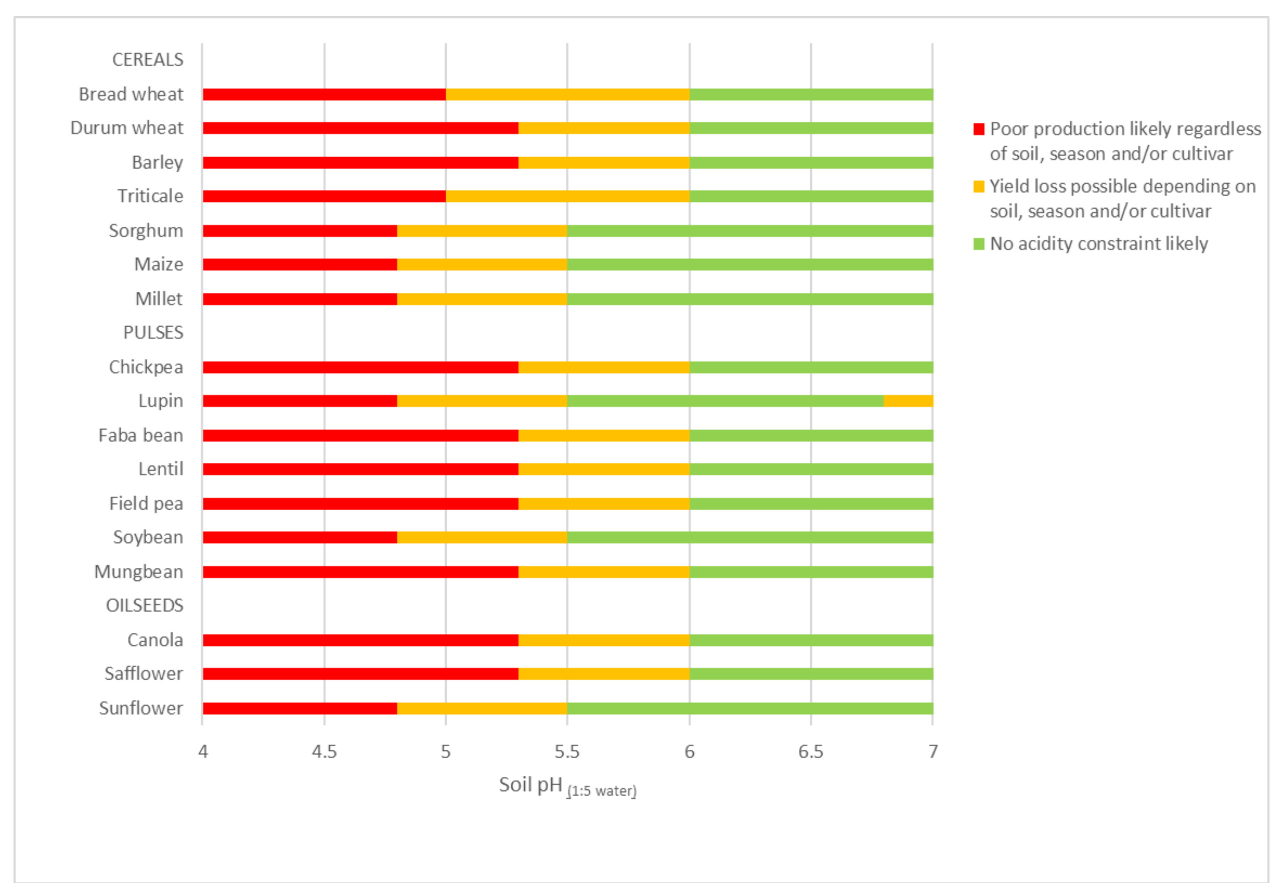

Figure 4. Soil $pH_{w1:5}$ tolerance limits proposed for crop species when grown under rainfed conditions in subtropical regions (Page et al., 2021).

Sodic soils

The literature report also indicated that tolerance to soil sodicity varies between species, although there is not currently enough information available to publish 'traffic light' boundaries for sodicity. However, it is clear that there are differences in the tolerance of different species and varieties to sodic conditions. Improving our understanding about which are the best species and varieties for areas with sodic soils is an important research priority and will help improve productivity, particularly when sodicity occurs in the subsoil and is difficult to ameliorate.

Tolerance to sodicity varies between cultivars of wheat

A limited number of cultivars have been tested at contrasting sites in several seasons

As part of a GRDC co-funded project 'Improving wheat productivity on sodic, saline and dispersive soils', (UA00159, 2015 to 2020), trials in Queensland were conducted at a highly-sodic site and a less-sodic site in each season to compare tolerance to soil constraints between certain wheat genotypes (Figure 5).

A key aim of this project was to characterise the tolerance to soil constraints of wheat genotypes in all the major Australian cropping regions. To achieve this, a core set of lines from all over Australia were tested in all regions. A small number of lines from Qld and NSW were included in each season. A comprehensive comparison of current commercial cultivars in each region was not a focus. However, data on the small number of Qld and NSW cultivars tested do show genotypic differences.

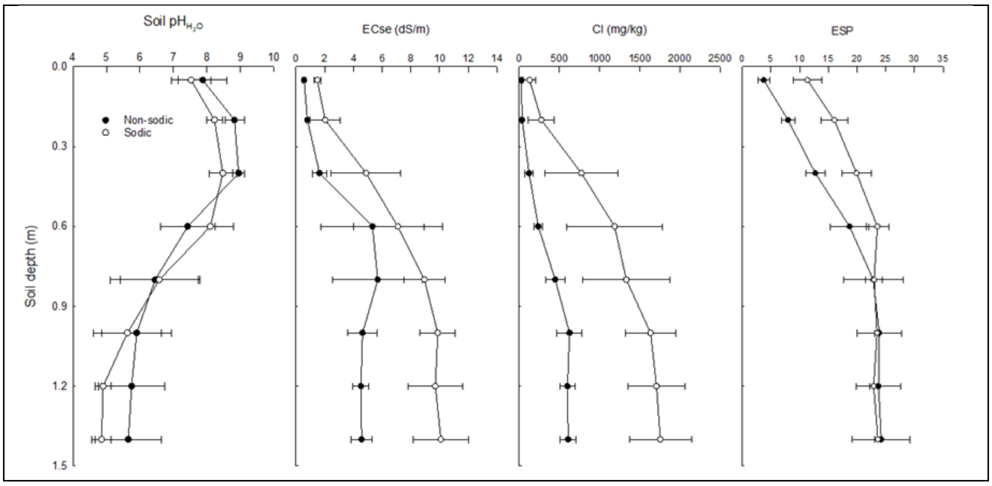

Figure 5. Average and standard errors of soil constraints for the less-sodic and highly sodic sites during 2015-19 experiments.

Soil and seasonal variability complicate field comparisons

The effects of soil constraints vary both spatially and temporally complicating attempts to compare genotypes in the field. Spatial variation in the field occurs both across the landscape and with depth in the soil profile (Figure 5). High levels of variation at the surface over distances of a few metres are common, particularly after levelling (Figure 6). There are also complex interactions among the various physio-chemical constraints (Nuttall et al., 2003). These complicated interactions can limit the agronomic and management options. Variability in the impact on the crop growth and yield is compounded by the complex interactions between the physiochemical constraints and environmental factors, particularly the timing and amount of rainfall relative to the crop development cycle. This leads to variation in genotype ranking from season to season and the ability to ascribe differences between genotypes to soil constraints.

Spatial variability

To find genetic differences in the presence of high spatial variability, it is necessary to have many plots for each genotype spread across the trial. During UA00159, 4 replicate plots per genotype were used in most years with 6 replicates in 2020. This compares to 2 or less replicates per genotype in standard multi-environment genotype trials. The need for such high numbers of replicates limits the number of lines that can be tested each year.

Figure 6. Drone image of a highly constrained trial site near Goondiwindi in 2020 showing spatial differences in canopy cover likely due to small scale differences in soil constraints.

We are currently using remote sensing information from drones to determine whether information on canopy cover might be used to compensate for some of the spatial variation in soils to improve detection of genetic difference.

Temporal variability

The ability to discriminate between genotypes for tolerance to sodic soils with variable subsoil constraints in field experiments varied greatly in each season during project UA00159 (Figure 7). In 2015 and 2016, higher than average in-crop rainfall meant that plants were less reliant on access to water from the soil. Thus, rankings in these seasons are less likely to be representative of tolerance to soil constraints.

Conversely, during 2019 when in-crop rainfall was extremely low, the high-constraints trial could not be harvested at all. In dry years more generally, genotypic differences are usually much harder to differentiate because of very low yield.

In years when in-crop rainfall is near the district average, as in 2017, 2018 and 2020, discrimination between genotypes was much better.

Discrimination for tolerant genotypes varies greatly with in-crop rainfall

Year	geno #	ICR (mm)	Yield (t/ha) Soil constraints Low	High		Diff %	Geno SSC diffs?
2015	36	209	4.06	3.64	ns	10.3	No
2016	38	325	4.02	4.00	ns	0.5	No
2017	44	132	1.61	0.37	*	77.0	Yes
2018	18	69	2.33	0.93	*	60.1	Yes
2019	22	<10	<0.5	0	NA	NA	No

Long-term average ICR = ca. 170 mm
District average yield 1.5-2.0 t/ha

Figure 7. Differences between mean yield at a highly sodic site and less sodic site in each season as well as differences in genotype ranking between sites were most evident in years where in-crop rainfall (ICR) and site mean yields were close to the district average.

Genetic differences in tolerance can be found

Despite the challenges discussed above, genetic differences between varieties could be identified particularly in seasons 2017, 2018 and 2020. In general, the yield ranking of genotypes at the less-sodic site was not a good indicator of the ranking at the highly sodic site. This indicates that testing on highly sodic soils is likely to be required to identify varieties best for those sites. For example, in 2018 the cultivars Corack⫯, Mitch⫯, Trojan⫯ and Mace⫯ ranked highly at the non-sodic site, while the wheat genotypes Flanker⫯, Corack⫯, Janz and Sunco ranked highly at the sodic site (Figure 8). However, given the small number of varieties tested to date, it is not yet possible to determine sufficient economic value that would provide useful grower advice on variety choice at this time.

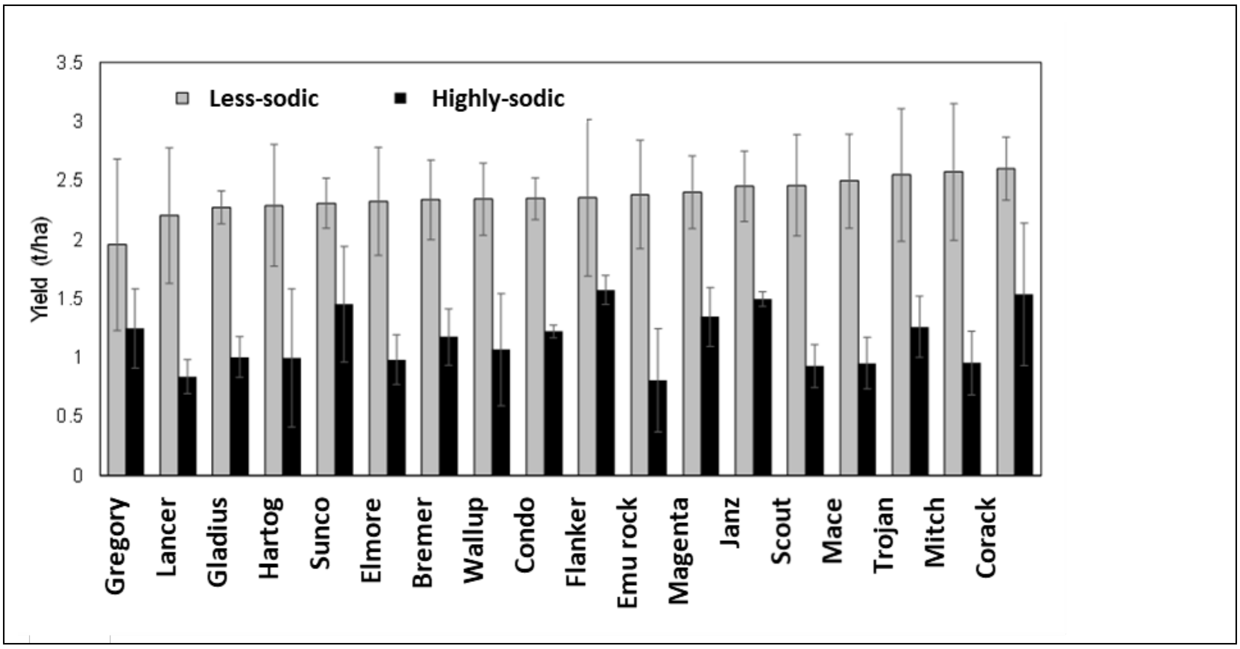

Figure 8. Mean grain yields of wheat lines at the sodic site in 2018, ranked in ascending order of yield at less-sodic site in 2018.

(⫯ The varieties Gregory, Lancer, Gladius, Elmore, Bremer, Wallup, Condo, Flanker, Emu rock, Magenta, Mace, Trojan, Mitch and Corack are protected under the Plant Breeders Rights Act 1994.)

Proxy traits could help identify prospective cultivars and breeding lines

Proxy traits are often used in research and breeding where the primary trait, in this case performance on sodic sites, is hard or expensive to measure. Field validation is always needed; however, proxy traits can sometimes be used to quickly identify genotypes most likely to perform well. Even if the proxy trait is not highly accurate in identifying the best performing lines, it may be useful to identify the vast bulk of lines that are not likely to be well adapted. This can reduce the number of lines requiring highly replicated field trials at multiple sites in multiple years.

Thus, proxy traits can potentially be used

1. To provide recommendations to growers, by helping identify the most prospective cultivars for expensive field testing
2. In breeding programs aiming to develop more tolerant lines, to screen out the bulk of low ranking lines.

Potential proxy traits have been identified

Potential proxy traits associated with tolerance to sodic soils with high Cl at depth include lower concentrations of Cl in the youngest mature leaf blades close to flowering as well as higher concentrations of calcium and potassium (Figure 8; Dang et al 2016).

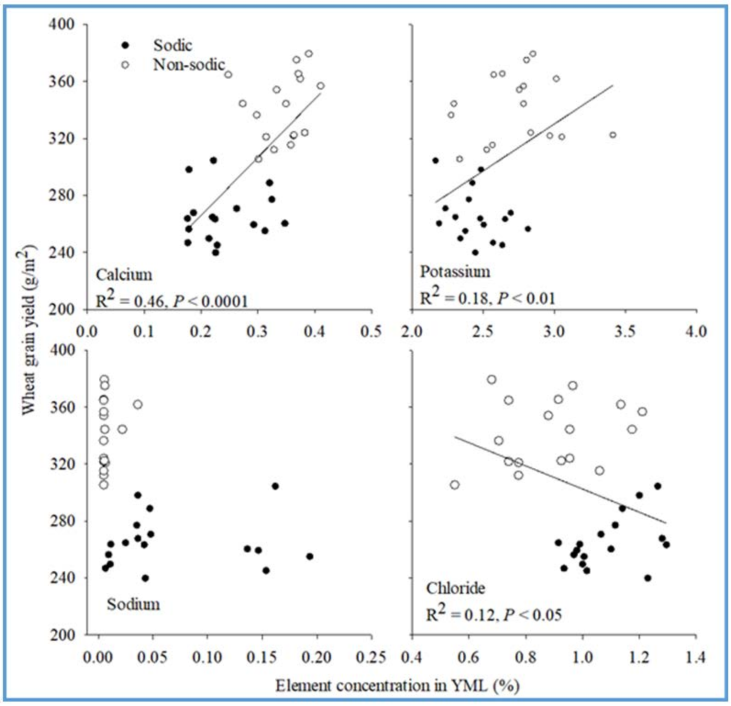

Figure 9. Concentrations of elements in the youngest mature leaf (TML) of wheat near flowering (Dang et al. 2016). Solid dots represent data for a highly sodic site and open dots a less-sodic site.

Additionally, a number of traits have been identified as associated with better establishment in the presence of a soil crust (which can often form on sodic topsoils). These include rapid germination, increased emergence force with greater hypocotyl diameter and narrower root angle (Anzooman et al. 2018, 2019).

Thus, choice of species and variety are important for optimising return on sites with soil constraints. The most tolerant species and variety differs depending on the most limiting constraint.

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Contact details

Dr Jack Christopher
UQ QAAFI, Centre for Crop Science.
Leslie Research Facility, PO Box 2282 (13 Holberton Street), Toowoomba
Ph: 07 4529 1314
Email: j.christopher@uq.edu.au

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ConstraintID – a free web-based tool to identify areas where soil constraints are most likely to be limiting crop yields

Yash Dang[1], Tom Orton[1], David McClymont[2] and Neal Menzies[1]

[1] School of Agriculture and Food Sciences, The University of Queensland
[2] DHM Environmental Software Engineering Pty Ltd

Key words

ConstraintID, soil constraints, crop yield, decision support tool, remote sensing, Landsat

GRDC code

UOQ1803-003RTX

Take home messages

- Better knowledge and understanding of the variation of past crop yields (both spatially across a paddock, and temporally from season to season) can help growers make better management decisions to improve yields in future
- Remote-sensing data compiled from earth-observing satellites provide a valuable information source about past crop yields, allowing us to look through multiple years of imagery for consistent patterns through time – that is, spatial patterns of yield variation that repeat season after season
- Such consistent patterns might imply the presence of some kind of soil constraint limiting yields in parts of the field
- This web-based tool enables growers to easily look at processed remote-sensing data representing past crop yields in their paddocks. The tool will show if there are any consistent spatial patterns in the data and will compile and present maps of soil constraints for comparison. The data on these driving factors could help the user to interpret the variation shown by the remote-sensing data.

Introduction

Within-field spatial variation of crop yields can occur for various reasons, but perhaps the most important driver of this variation is the soil. There are different management strategies available to growers to address soil constraints (amelioration, adjusting inputs to match potential, switching to growing tolerant species), but a necessary first step is the identification of affected areas (Dang et al., 2010).

Persistent spatial patterns of yield variation within fields that have otherwise been managed uniformly (spatially) provide an indication that soil constraints are driving variation. Remotely sensed data from satellites provide a valuable information source for helping with the task of identifying persistent yield patterns (Orton et al., 2018). In particular, the Landsat series of satellites provide a very useful dataset for several reasons:

(i) The long history (in this area of data collection from 1999-present), which allows persistent spatial patterns of within-field yield variation (similar patterns repeating season after season) to be identified
(ii) The time between repeated images of the same area (8 days when two of the Landsat satellites are operating), which allows growth patterns within a season to be identified
(iii) The spatial coverage of satellite data (data readily available across the whole region)

(iv) The spatial detail (30-m pixel sizes), which is detailed enough to allow within-field patterns of spatial variation to be identified, and
(v) It is freely available.

While Landsat imagery provides an excellent source of raw data, there are a number of processing and analysis steps required to extract the potentially useful information. We have developed a freely available online software tool, ConstraintID (http://constraintid.com.au), to make this task easy for growers, and to present results in a way that is straightforward to interpret. The tool should assist growers with identification of potentially constrained areas, giving them the information to make more informed management decisions. Here we present an illustration of the software tool applied to a field in northern NSW.

Illustration

Remote-sensing data to give crop performance information for all years

The software undertakes the spatial analysis within the confined boundary of a field. It is important that there has been consistent management across the field, so that spatial differences due to management will not be confused with differences due to soil constraints. The software then collates all of the remote-sensing data for this field, and for each year from 1999 to the latest complete season, generates a map of an index representing crop performance. This aim of this index is to show, for any given year, which parts of the field were above average and which parts were below average. In some of these years a winter crop might not have been grown, so the software looks at the growth patterns within each season to check whether the field has been cropped and determines if it that years observations should be included in the analysis. For illustration, Figure 1 shows the resulting maps for the years 2005-2010 at Sunbury. In this case, the software deemed that there was good evidence of 2005, 2006, 2008 and 2009 being cropped years (shown by the green ticks), so these would be included in further analysis.

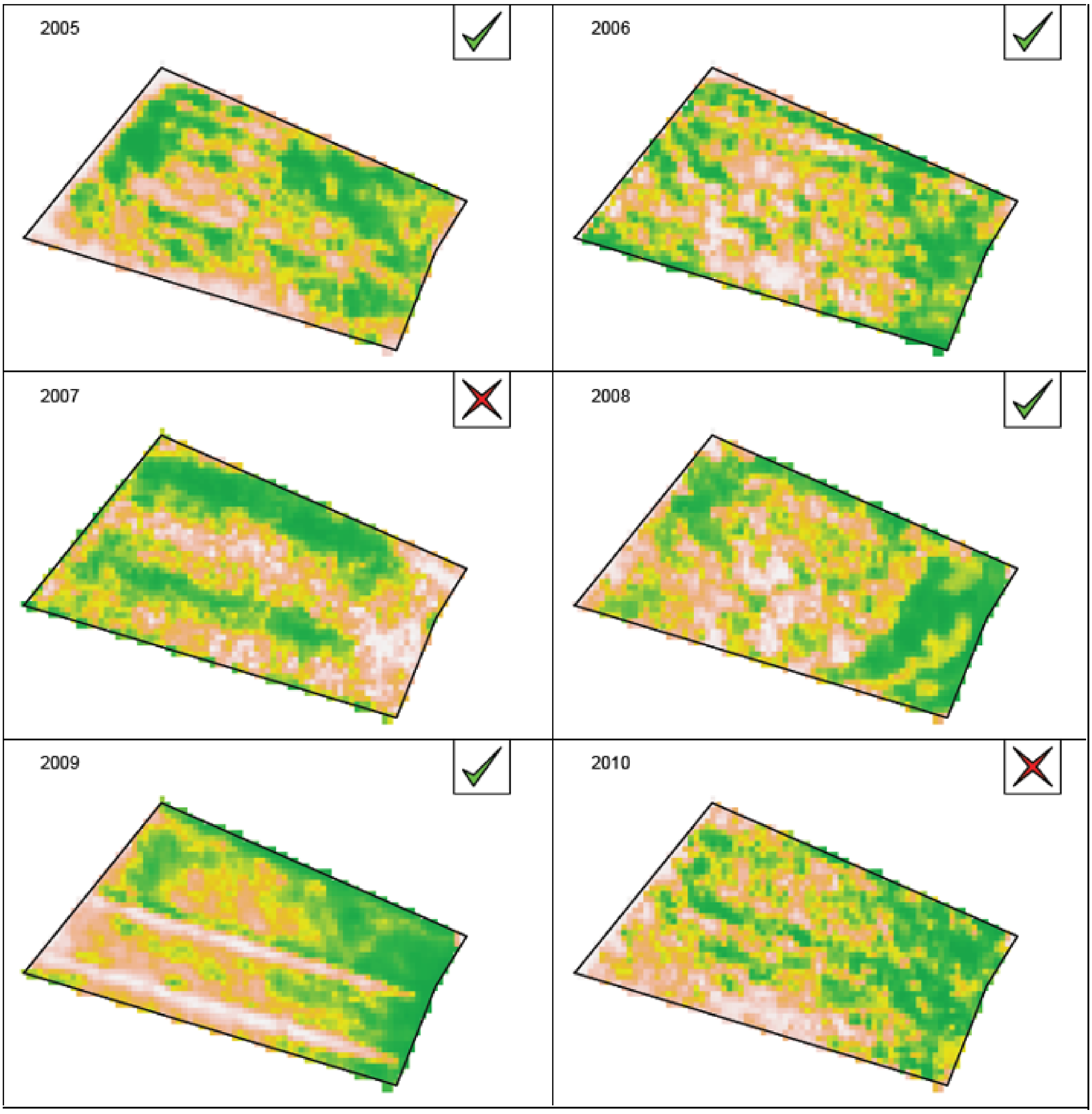


Figure 1. Maps of the index representing the spatial distribution of crop performance at Sunbury for the years 2005-2010. Green (darker areas) shows relatively good crop performance, beige relatively poor. The tick or cross in the corner of each panel indicates whether the analysis deemed that year to have been cropped or not.

Consistent spatial patterns in the remote-sensing data

It is important to note that the spatial pattern of the index has some aspects that repeat year after year, and other aspects that do not repeat. For example, in Figure 1 it seems that the east of the field was consistently higher yielding than the west. Also note that this was not the case in 2007, though for that year the field was deemed to not have been cropped. This highlights the importance of having a multiyear analysis when the goal is to identify soil constraints, which we would expect to give rise to similar spatial patterns of yield year after year (as opposed to diseases or weeds which might give reduced yields in part of the field in isolated seasons).

To identify the patterns that repeat season after season, the long-term average of the index is calculated for each pixel (using only the years when a crop was grown). A statistical test is then performed to evaluate whether there is evidence that a pixel consistently performs above or below average. Figure 2 shows an example of this type of analysis, from which it is clear that the east side of the field gave consistently better performance than the west side. Within some fields there will not be strong variation in soil constraints, and then we might not expect much consistent variation in yields. However, for fields where soil constraints exhibit strong within-field variation, we would expect a consistent pattern of spatial variation, such as that illustrated in Figure 2.

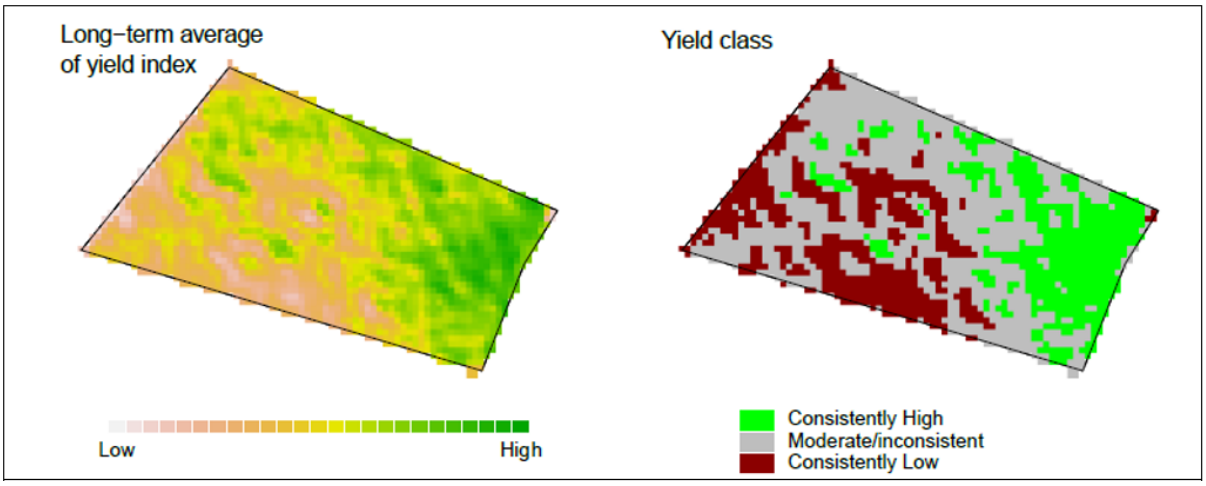


Figure 2. Maps summarising the multi-year analysis of remote-sensing data at Sunbury.

Comparing the remote-sensing information with soil data

The maps shown so far are based only on analysis of the remote-sensing data. Soil data from within the field are vital to validate what is causing the variation in yield. Information from the remote-sensing analysis (Figure 2) can be used to select locations for soil sampling. An advisable strategy might be to collect soil cores to a depth of 1.2 m from a few locations (minimum 3-4) in the areas with consistently high values of the crop yield index (green (mostly to the east) areas in Figure 2) and from a few locations in the consistently poor-performing areas (red (mostly to the west) areas in Figure 2). Once a dataset of soil analysis results from profiles in the field has been compiled, the software tool allows the user to upload/input the data, and it can be used to compare soil constraints in the in the good and poor-performing areas of the field.

For the Sunbury field, ten soil profiles were collected, of which two profiles were in the areas with consistently low crop yield index values, and three were in the consistently high yield index areas. The soil constraint data from the profiles in the better-performing areas are averaged and plotted as the green lines (generally to the left) in Figure 3; the red lines (generally to the right) show the averages from the poor-performing areas. Also shown are critical values for potential (light orange background - on left) or severe effects (light red background – on right) of the soil constraints on wheat yields. These critical values have come from a recent review of the literature on soil constraints to cropping in Australia (Page et al., 2020).

These plots indicate that there are differences in the salinity of the soil profiles from the constrained and unconstrained areas, with the profiles from the constrained areas exceeding the critical values for severe salinity effects below around 40cm in the soil profile. The differences between the constrained and unconstrained profiles in terms of sodicity were not as great.

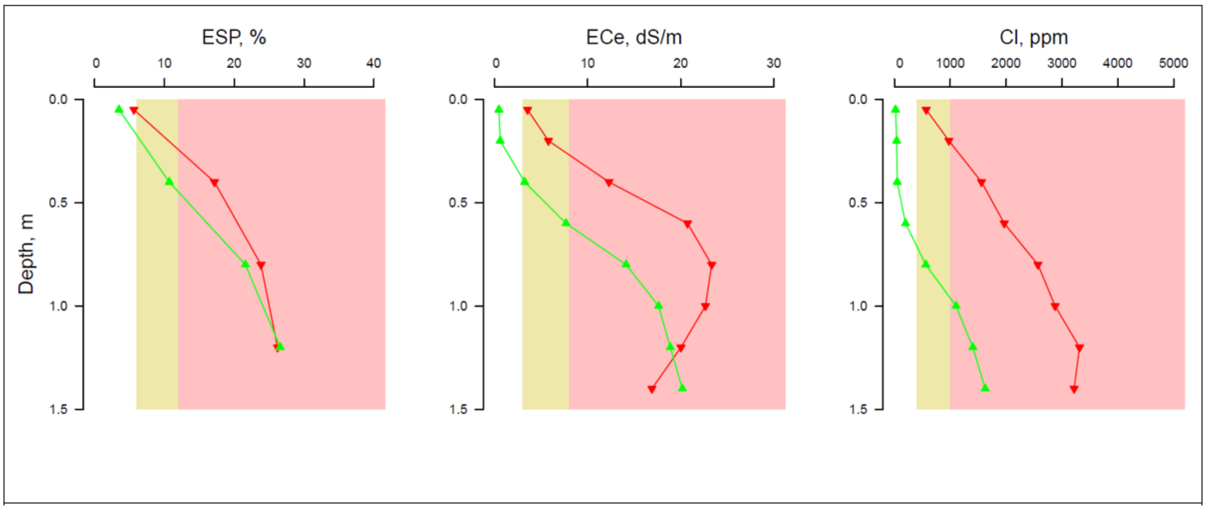


Figure 3. Soil profiles within the areas with consistently high crop yield index values (green - line to left) and consistently low values (red – line to right). More severely constrained zones are delineated by colour coding and are to the right side of each graph.

Web-based ConstraintID (http://constraintid.com.au/)

The web-based interface of Constraint ID allows farmers and consultants to setup, save and share soil constraint analyses for different paddocks (Figure 4).

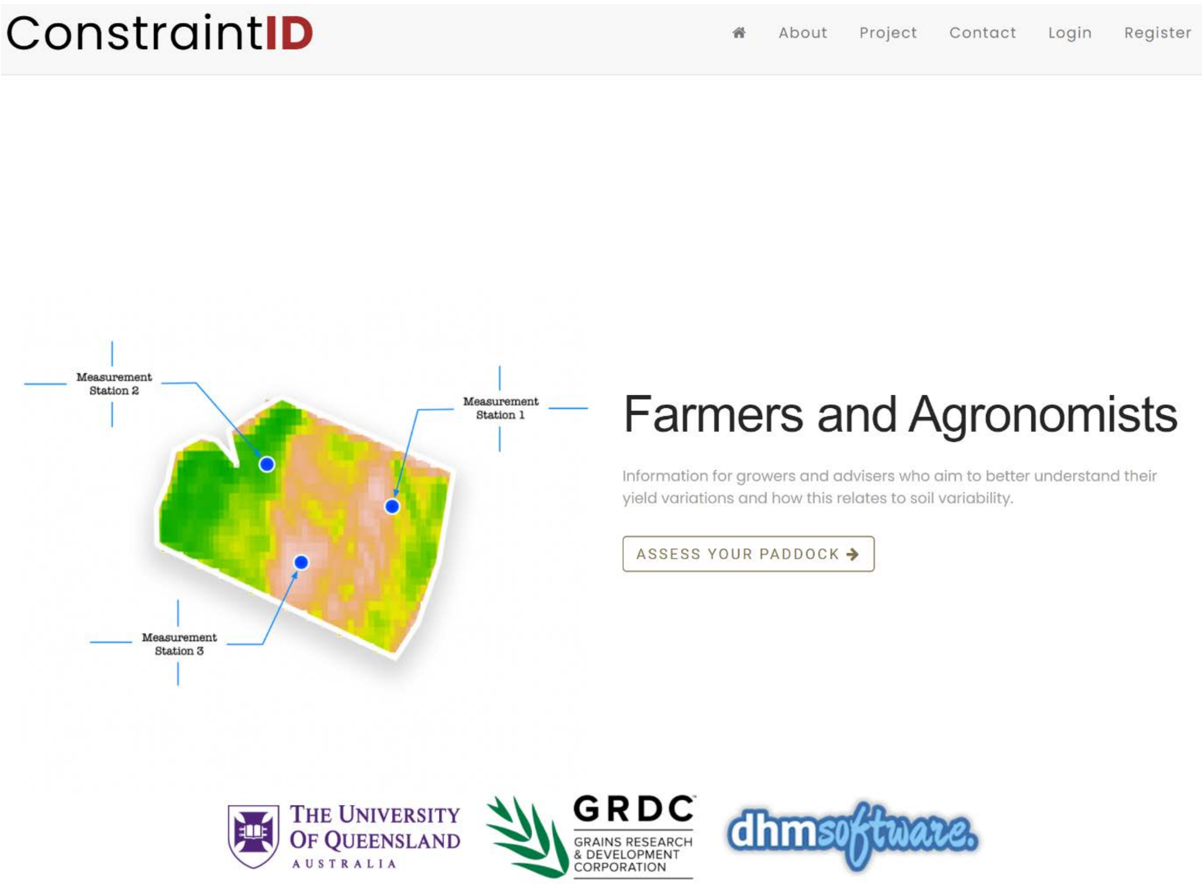
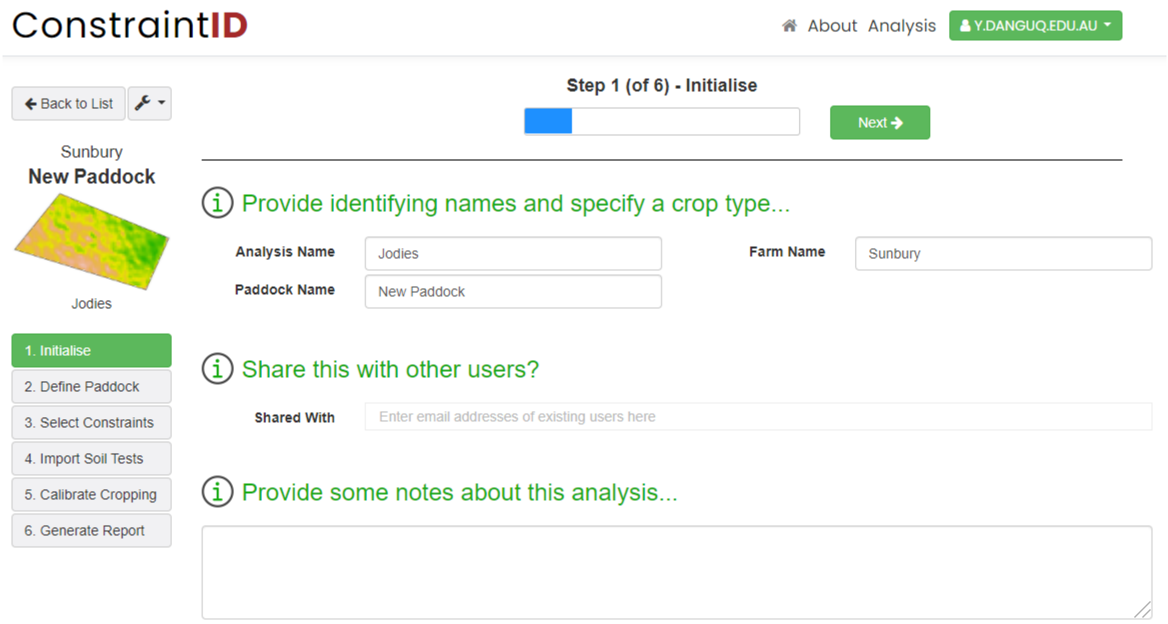


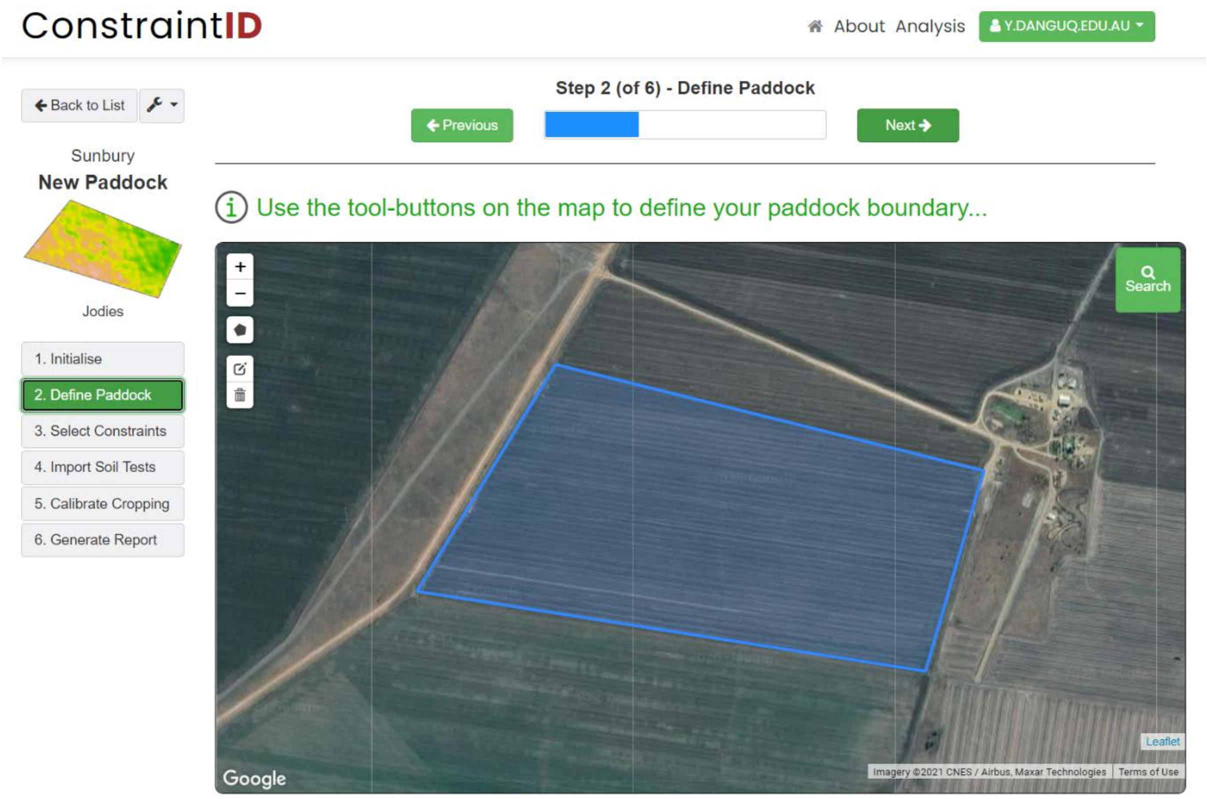
Figure 4. ConstraintID landing page

An analysis is broken down into 6 steps presented through the interface:

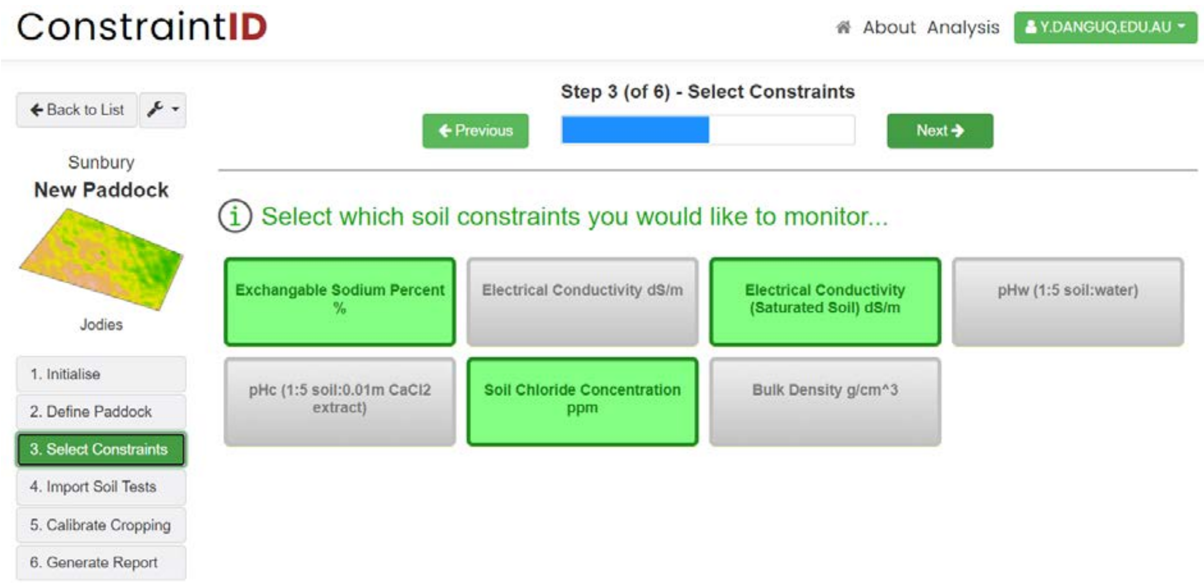
Step 1: Enter analysis details



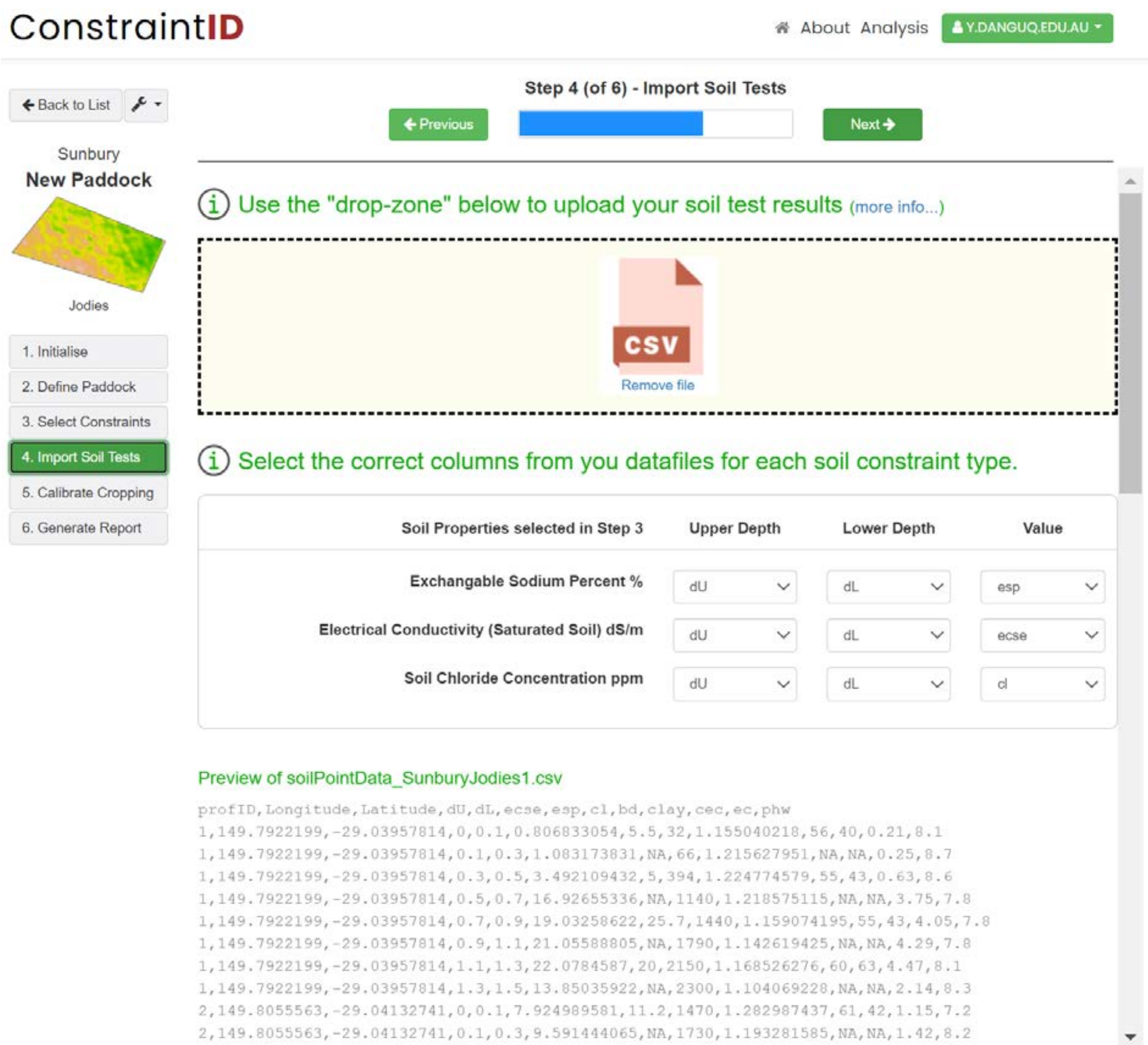
Step 2: Define paddock boundary



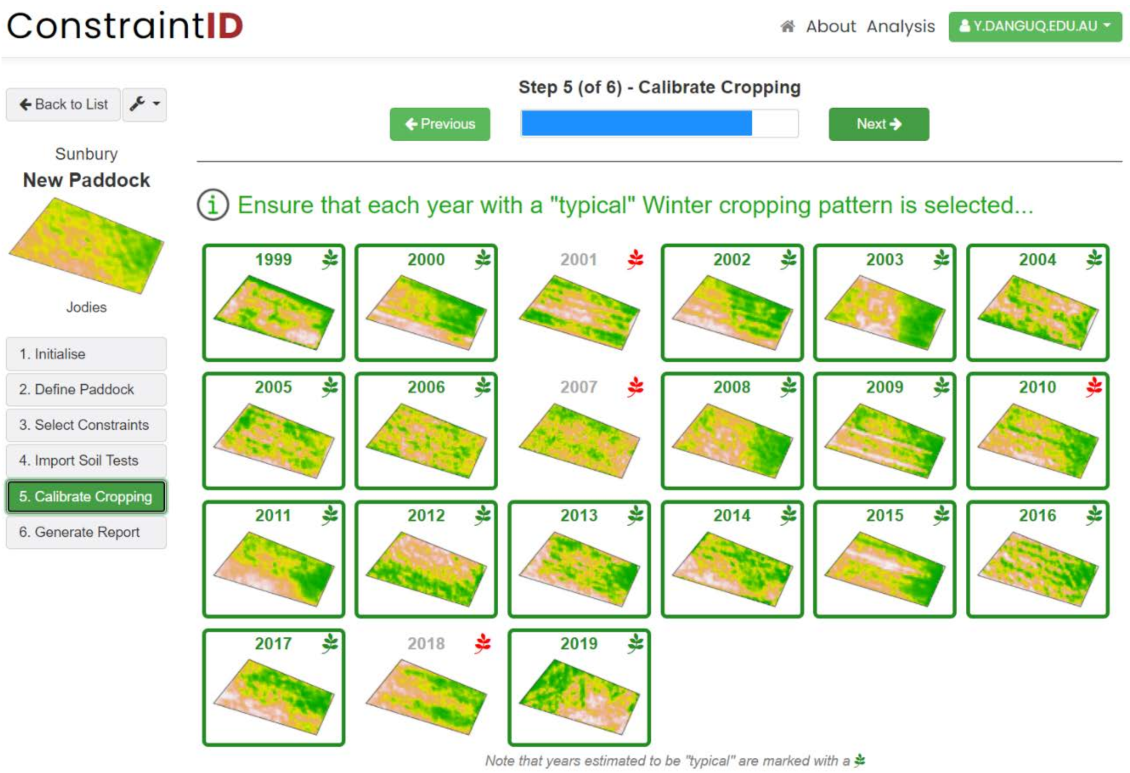
Step 3: Select soil constraints



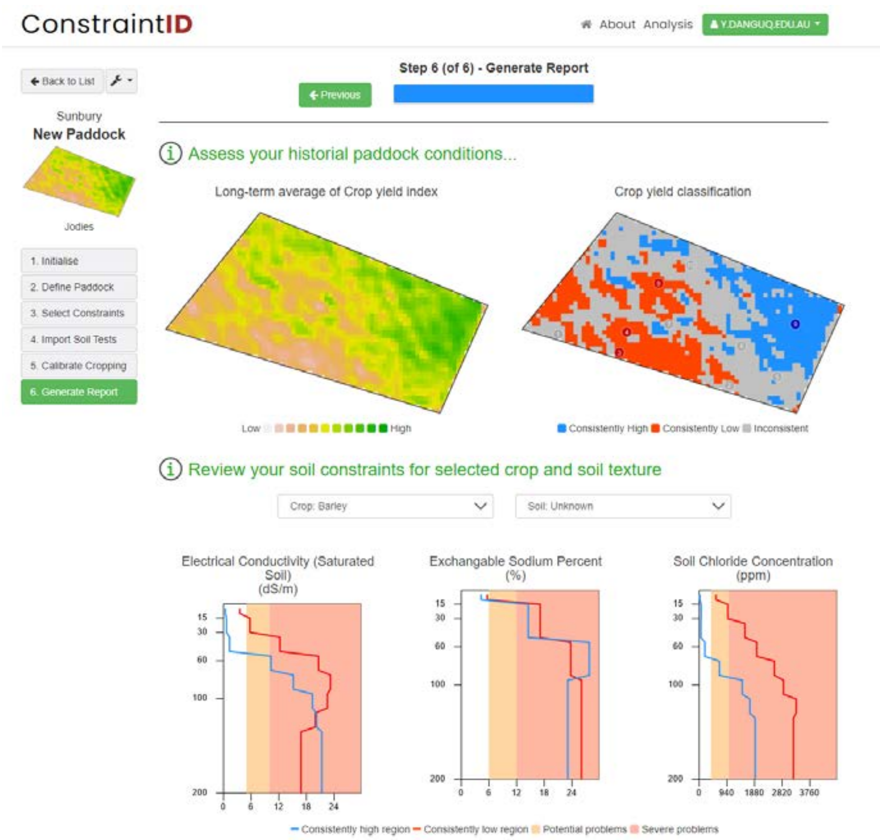
Step 4: Import soil test data



Step 5: Select cropping years



Step 6: Review results



For each analysis, the software requires the user to trace their paddock boundary over a Google Maps' satellite image, using tools provided in Step 2. This then initiates the start of the spatial analysis which occurs silently in the background on the server. In this process, a time-series of 'Enhanced Vegetation Index (EVI)' satellite images from 1999 to the present date are extracted which typically include up to 20 images (days) per year. These tiled images are then reprocessed to exclude any data outside of the paddock boundary. In some cases, multiple adjoining images may require stitching together when the paddock boundary extends past the tile boundary. The resulting paddock images are then filtered to remove any that might be affected by excessive cloud cover or are indicative of fallow conditions. Finally, the individual EVI pixel values are ranked in order across the paddock to differentiate between high vegetation and low vegetation areas of the paddock. A single image is then produced for each year, based on averaging the ranked EVI values for that year, which we designate as the Crop Yield Index (CYI). This process typically takes 10-20 seconds to complete.

In the next steps (3 & 4), the user selects which soil constraints they wish to analyse and upload any measured soil test data they have relating to these constraints. Soil test data must be prepared in a comma-separated value format and uploaded to the server via dragging and dropping the data files into the user interface. Users must then identify which columns in the data files correspond to each soil constraint using in-built selection tools.

The second last step of the analysis involves the user being presented with a series of paddock images (generated in the second step) showing the Crop Yield Index across the paddock for each year. Each image is 'marked' to show whether or not the software thinks that that year was indicative of a typical cropping year. The user must then inspect each image to ensure that all typical cropping years are selected, and non-cropping years are de-selected. This in effect is calibrating the analysis in order to generate the final result.

In the final step of the analysis, all included cropping years are compiled into a single paddock map of Crop Yield Index values. A second image is then generated identifying those regions of the paddock that have demonstrated consistently high Crop Yield Index values (coloured blue) or consistently low values (coloured red). The locations of the soil test readings are then overlayed on these regions, allowing a graph of each soil constraint to be generated based on the soil test results, with different lines for high and low yielding areas.

Summary

The work presented here provides a snapshot of the Constraint ID software, which we think should provide growers with a valuable tool for investigating within-field variability and for making more informed management decisions. Further work to investigate and compare different management strategies once constrained areas have been identified is imperative.

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Contact details

Dr Yash Dang
School of Agriculture and Food Sciences
203 Tor Street, Toowoomba
Ph: 0427 602 099
Email: y.dang@uq.edu.au

Amelioration for sodicity - deep ripping and soil amendment addition across NSW and Qld. Engineering challenges. Yield responses to ripping, gypsum and OM placement in constrained soils

David Lester[1], Cameron Silburn[2], Craig Birchall[3], Richard Flavel[3], Chris Guppy[3], John Maclean Bennett[4], Stirling Roberton[4], David McKenzie[5]

[1] Department of Agriculture and Fisheries Queensland, Toowoomba
[2] Department of Agriculture and Fisheries Queensland, Goondiwindi
[3] University of New England, Armidale
[4] University of Southern Queensland, Toowoomba
[5] Soil Management Designs, Orange

Key words

yield maps, soil testing, ground truthing, dispersion, sodicity, ripping

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Take home messages

- Benefits of subsoil amendments are more likely in poorer seasons
- Adjustment in agronomy may be necessary to take advantage of improved subsoil conditions
- Considerable challenges remain in identifying engineering solutions to deeper amendment applications.

Background

Model analyses suggest a yield gap between water-limited potential yield and currently achieved production exists across northern Australian grain regions. This yield gap is a function of physical, chemical and biological factors in each soil, including capacity of soil to store and release water for efficient plant use. Many regions where yield is constrained contain dispersive soil within the surface 50cm and deeper. Sodicity (a high exchangeable sodium percentage) is a major cause of aggregate dispersion and may compromise soil structure. Dispersive behaviour decreases both soil water availability and nutrient acquisition, increases risk of runoff and erosion, and impairs biological (soil microbial and plant root) activity. Acidity, salinity (presence AND absence) and compaction further constrain yield potentials. However this project focuses on sodicity as the major constraint with often related constraints considered as compounding and/or interacting factors.

Amelioration of subsoil constraints is an expensive process. The engineering challenges and energy requirements are significant. It is important to acknowledge that production benefits from subsoil amendment are more likely to be observed in poorer seasons. In good seasons, root function and activity, and soil moisture, will be able to sustain yield from surface activity and extraction where soils are often less constrained. However in poorer seasons where subsoil moisture is required to finish a crop, subsoil amelioration will have a proportionately larger impact on yield. Hence, we expect that the return on investment in subsoil amelioration to be larger in poorer seasons, than in higher decile seasons with more growing season rainfall.

A series of linked investments is assessing the economics of ameliorating constrained surface and sub-surface soils in the northern region. The program has four areas covering:

(i) Spatial soil constraint identification

(ii) Amelioration and management of soil constraints
(iii) Economics of adoption, and
(iv) An overarching communications and extension program.

The research into soil amelioration and management has two components led by the University of Southern Queensland (USQ). First is a set of six small-plot core experiments exploring detailed amelioration research. There are three sites in northern and central New South Wales (NSW) managed by the University of New England (UNE), and three sites in southern Qld managed by the Department of Agriculture and Fisheries (DAF).

This paper covers the challenges of core site implementation, describes the treatments being studied and the adaptations needed to deliver these treatments to depth in our constrained soils. It also extends to discussing the realities of attempting this process at a commercial scale. Finally it reports on the first season of field trial responses.

Core site selection

The USQ team undertook extensive surveying of 30 fields across central and northern NSW and southern Qld. The areas were clustered around 6 locations (Trundle, Armatree, Spring Ridge, Talwood, Millmerran and Meandarra), with 5 fields surveyed at each. Field surveying included capture of yield maps if available, satellite NDVI imagery, and soil mapping with EMI. Using a combination of yield, site elevation and EMI maps, bare soil colour imagery and grower experience, four survey points where selected for soil sample collection and analysis. After consolidating data 'core' experimental sites where selected in each of the six hub areas: three in NSW and three in Qld.

Core site characterisation

All sites were generally alkaline in the upper profile with an exchangeable sodium percentage (ESP) well over the 6% nominal threshold for healthy crop growth. Profile chloride (Cl) values were generally low, indicating that sodicity was likely to be the primary restriction.

Chemical characteristics of the six core experiments are below:

Location: Armatree
Soil type: Brown Sodosol, not dispersive (0-10cm) to dispersive (10-20) surface, to strongly alkaline and dispersive at depth, compact surface layers

Depth	pH	pH	EC	Ca	Mg	Na	K	ECEC	ESP	Cl	P
(cm)	(H_2O)	($CaCl_2$)	(1:5)	(cmol/kg)					%	(mg/kg)	(mg/kg)
0-10	6.0	5.3	0.20	3.7	3.4	0.91	1.00	9.0	10		58
10-20	7.8	6.8	0.20	8.5	7.9	2.63	0.83	19.9	13		7
30-40	9.3	8.3	0.45	13.1	12.6	5.78	0.81	32.3	18		8
60-70	9.4	8.4	0.58	12.3	13.4	6.35	0.96	33.0	19		6

Location: Forbes
Soil type: Brown Vertosol, not dispersive (0-10cm) to dispersive (10-20) surface, to strongly alkaline and dispersive at depth

Depth	pH	pH	EC	Ca	Mg	Na	K	ECEC	ESP	Cl	P
(cm)	(H_2O)	($CaCl_2$)	(1:5)	(cmol/kg)					%	(mg/kg)	(mg/kg)
0-10	6.3	6.1	0.39	8.7	7.7	2.13	0.77	19.3	11		89
10-20	7.9	6.9	0.30	15.4	10.2	4.76	0.55	30.9	15		12
30-40	9.1	8.2	0.64	12.5	11.3	8.14	0.49	32.5	25		4
60-70	9.1	8.3	0.85	11.3	10.4	9.57	0.56	31.9	30		1

Location: Spring Ridge
Soil type: Black Vertosol, moderate ESP and salinity in surface, increasing to high ESP and salinity at depth, but both are non-dispersive due to the salinity

Depth	pH	pH	EC	Ca	Mg	Na	K	ECEC	ESP	Cl	P
(cm)	(H_2O)	($CaCl_2$)	(1:5)	(cmol/kg)					%	(mg/kg)	(mg/kg)
0-10	8.2		0.54	31.7	41.7	3.3	2.4	79.1	4		100
10-20	8.2		0.62	37.2	43.5	5.2	1.4	87.3	6		
30-40	8.3		1.94	31.0	51.5	13.9	1.0	97.4	14		
60-70	8.3		2.52	28.7	56.7	19.5	1.1	106	18		

Location: Dulacca
Soil type: Grey/Brown Vertosol (nominally Ulimaroa). Surface soils not spontaneously dispersive, subsurface highly dispersive.

Depth	pH	pH	EC	Ca	Mg	Na	K	ECEC	ESP	Cl	P
(cm)	(H_2O)	($CaCl_2$)	(1:5)	(cmol/kg)					%	(mg/kg)	(mg/kg)
0-10	8.5	7.7	0.21	18.1	8.0	2.73	0.93	29.8	9	43	9
10-20	8.8	7.8	0.25	15.8	9.8	3.99	0.61	30.3	13	53	14
30-40	8.1	7.3	0.46	15.4	12.3	7.10	0.45	35.3	20	102	4
60-70	6.8	6.7	0.66	12.0	12.8	8.83	0.48	34.1	26	275	8

Location: Millmerran
Soil type: Grey/Brown Vertosol (nominally Moola). Surface and subsurface soils not spontaneously dispersive, very compact soil through the profile.

Depth	pH	pH	EC	Ca	Mg	Na	K	ECEC	ESP	Cl	P
(cm)	(H_2O)	($CaCl_2$)	(1:5)	(cmol/kg)					%	(mg/kg)	(mg/kg)
0-10	6.6	6.3	0.15	8.4	6.6	2.37	0.31	17.7	13	153	38
10-20	8.7	7.4	0.24	10.6	9.0	3.36	0.20	23.2	14	330	5
30-40	6.9	6.2	0.38	9.5	15.	6.82	0.14	31.4	22	428	3
60-70	6.4	5.5	0.43	10.2	16.4	8.79	0.18	35.5	25	457	2

Location: Talwood
Soil type: Red/Brown Vertosol (nominally Arden). Surface soils not spontaneously dispersive, subsurface highly dispersive at 60-70cm.

Depth	pH	pH	EC	Ca	Mg	Na	K	ECEC	ESP	Cl	P
(cm)	(H_2O)	($CaCl_2$)	(1:5)	(cmol/kg)					%	(mg/kg)	(mg/kg)
0-10	8.3	7.6	0.17	27.5	4.7	1.8	1.3	35.5	11	22	18
10-20	8.7	7.9	0.23	27.8	7.0	3.8	0.7	39.3	10	26	3
30-40	8.9	7.8	0.36	22.5	9.4	7.0	0.4	39.4	18	73	2
60-70	9.2	7.9	0.44	20.3	9.9	9.9	0.5	40.7	24	163	2

Experiment treatments

This research focussed on eliminating sodium as a constraint for the upper 50 cm of a soil profile. It was 'proof-of-concept' research, intended to explore effects on soil water storage and grain yields under gypsum application rates to remediate the ESP to ≤ 3% in either or both of the top 20 cm of soil and half of the soil volume in bands from 20 cm down to 50 cm depth. Organic matter (OM) also acts to limit aggregate dispersion (as well as providing nutrients at depth) and, whilst not reducing ESP, may act to improve water holding capacity and pore stability. Gypsum rates (often ≥ 15 t/ha) were compared against a high rate subsoil (≈ 20 cm deep) compost (Qld)/lucerne pellet (NSW) application (≈ 10 t/ha), and the application of elemental sulfur to dissolve calcium carbonate to produce gypsum in-situ and lower alkalinity.

The rates chosen are considerably higher than the likely economically viable rates and were deliberately chosen to determine if subsoil remediation to remove dispersive constraints would result in improved production outcomes beyond the first year. With that in mind, it is worth considering that the cost in diesel of ripping to depth without adding the necessary amendment is unlikely to be recovered. Repeated, smaller gypsum/OM applications coupled with deep ripping to place them is cost prohibitive. Hence, single, large, additions may ultimately be best practice.

Similar treatment structures are used in both NSW and Qld, with both physical and chemical ameliorants, a range of options exploring impacts and/or interactions between tillage (shallow and deep), deep placement of nutrients (as inorganic or organic forms), surface and subsurface applications of gypsum to reduce ESP to < 3%, incorporating organic amendments (lucerne pellets in NSW and composted feedlot manure in Qld), and applying elemental sulfur (ES) to decrease soil pH and generate gypsum in situ (Table 1).

Surface gypsum treatments were spread onto the soil, and then incorporated by ripping to 20 cm. Actual application rates for gypsum varied with each site based on calculations that capture the required Ca to lower the ESP to <3%, but the overall structure of the experiment stayed the same.

The applied gypsum rate for subsurface placement was banded with 50% of the total needed for the whole 20 to 50 cm layer of soil. For example, if a total of 20 t/ha of gypsum was theoretically needed to remediate the entire 20 to 50 cm layer, in this application 10 t/ha was applied to ensure the right amount of gypsum within each band (assuming the band covers 50% if this zone). In NSW, it was assumed that the band only treated 25% of the profile, so only 25% of the total gypsum needed was applied – 5 t/ha in the example. Further details on how it was applied are outlined later in this paper.

Table 1. Treatment structure for core soil constraints sites in southern Queensland

Treatment	Rip (≈ 20 cm)	Surface Gyp	Deep NP(K)Zn (≈ 20 cm)	Rip > 20 cm	Deep Gyp (≈ 20 cm)	Deep OM (≈ 20 cm)	Deep ES (≈ 20 cm)
1							
2	Y						
3	Y		Y				
4	Y	Y	Y				
5	Y		Y	Y			
6	Y		Y	Y	Y		
7	Y	Y	Y	Y	Y		
8	Y	Y	Y				
9	Y	Y	Y	Y			Y
10	Y	Y	Y (*)	Y			
11	Y	Y		Y		Y	
12	Y	Y		Y		Y	Y
13	Y	Y		Y	Y	Y	Y

Deep NP(K)Zn rate is 50 kg N, 30 kg P, 50 kg K and 1.5 kg Zn apart from * rate which matches N and P addition from deep compost application. Gyp = Gypsum, OM = Organic matter ES = elemental sulfur

Engineering and application challenges

Application rates for all ameliorants are substantial, with rates often greater than 6-10 t/ha being applied. With such large amounts of product required, logistically it is challenging to source, transport and apply the treatments at each site, especially with deep (~20 cm) applications.

Applicators are not going to be universally capable machines for putting ameliorant at depth – it is very challenging to engineer something to measure and distribute all manner of materials. The deep placement machine used in Qld required amendments with the physical characteristics of being relatively fine and easily flowable in order to be metered and delivered to depth. This was achieved by using 6 mm screened feedlot compost, and air drying natural mined gypsum to reduce moisture content. All materials were screened at the top of the applicator bin through a 12mm screen to further exclude lumps. In NSW, flow problems were resolved by using pellets and prills – a more expensive solution.

Metering of products was achieved through fluted rollers (Figure 1). Further changes were undertaken adapting it for use in the soil amendment experiments. Modifications included 75 mm chutes for amendment delivery down the back of the applicator tine and inclusion of a crumble roller for smoothing the surface slightly.

Figure 1. Metering unit for amendment application on the Qld research machine, with ruler for scale.

Given the 'proof-of-concept' intent of much of the research, interpretation of individual specific effects is challenging. What the research outcomes do confirm is there exists a significant upside in yield achievable with combinations of physical and chemical inputs.

Grain yield

Millmerran was planted to sorghum for 2019-20, while Dulacca, Armatree, Forbes and Spring Ridge all had winter crops in 2020. While experiments are similar across the Qld and NSW components, the results for the different states are reported separately.

Grain yield responses in Qld

In Qld, yield increases have been recorded at both the harvested sites. At Millmerran (Table 2), grain yields increased up to ≈25% or 750 kg/ha. In general, treatments with combinations of surface gypsum and subsurface NPK (i.e. trt 4, 7, 8 and 13) had the largest yield gains.

Table 2. 2019-20 Grain yield (GY) for sorghum at Millmerran

Trt		Yield	SE	Delta GY	Rel GY%	LSD*	Protein
1	Control	2970	133	0	0	a	11.1
2	Shallow rip	2910	188	-60	-2	a	10.7
3	Banded fert	3300	188	330	11	abcd	10.7
4	Surface gyp + shallow rip	3580	133	610	21	bcd	10.4
5	Deep rip	3430	188	460	15	abcd	10.6
6	Deep gyp	3120	188	150	5	ab	10.9
7	Surface + deep gyp	3750	133	780	26	d	10.7
8	Surface gyp + deep rip	3750	188	780	26	cd	10.2
9	ES + surf gyp	3250	188	280	10	abc	10.6
10	Nutrient control	3500	188	530	18	bcd	11.0
11	Surface + deep OM	3370	188	400	13	abcd	10.4
12	ES+OM	3360	188	390	13	abcd	10.5
13	All	3700	188	730	25	cd	10.5

* Treatments with the same letter do not significantly differ ($P<0.05$)

At Drillham (Table 3), grain yields increased up to ≈60% or 1,250 kg/ha. Three treatments in particular provided the largest increases, treatments 10, 12 and 13. Commonality of these treatments is all have tillage to 30 cm, and either have high nutrient supplies from the high NP rates (treatment 10), or the composted feedlot manure (12 and 13). Deeper ripping (to 30cm) and lower nutrient inputs (50N,30P) increased yields by 800 kg/ha (40%), but it appears the higher nutrient supply plots allowed greater yields to be recorded.

Table 3. 2020 Grain yield (GY) for wheat at Drillham

Trt		Yield	SE	Delta GY	Rel GY%	LSD*	Protein
1	Control	2110	66	0	0	a	13.7
2	Shallow rip	2200	133	90	5	ab	13.5
3	Banded fert	2520	133	410	20	bcd	14.4
4	Surface gyp + shallow rip	2320	133	210	10	abc	14.0
5	Deep rip	2990	133	880	42	fgh	13.3
6	Deep gyp	2860	133	750	35	defg	13.8
7	Surface + deep gyp	2580	133	470	22	bcde	13.8
8	Surface gyp + deep rip	2910	133	800	38	efg	13.8
9	ES + surface gyp	2690	133	580	27	cdef	13.5
10	Nutrient control	3310	133	1200	57	hi	13.9
11	Surface +deep OM	3010	133	900	43	fgh	13.7
12	ES + OM	3200	133	1090	52	ghi	13.6
13	All	3420	133	1310	62	i	13.6

* Treatments with the same letter do not significantly differ (P<0.05)

Grain responses in NSW

The Armatree site produced a 4.5t/ha crop at around 15% protein and had significant differences between treatments in both grain yield, and biomass at flowering (Table 4). In general, deep ripping and the addition of nutrients, as banded fertiliser or contained in the organic amendment, increased growth and yields by approximately 20%. However, the organic matter treatments (11-13) ran out of water during grain fill due to the very large biomass produced, resulting in similar yields to the controls, with higher protein and screenings levels.

Table 4. 2020 Grain yield (GY) for wheat at Armatree

Trt		Yield	SE	Delta GY	Rel GY%	LSD*	Protein	Screenings
1	Control	4470	188	0	0	abcd	15.5	0.8
2	Shallow rip	4740	210	270	6	abcde	15.8	1.2
3	Banded fert	5040	210	570	13	abcde	14.8	0.9
4	Surface gyp + shallow rip	5210	210	740	17	bcde	15.4	1.2
5	Deep rip	5390	210	920	21	cde	14.7	1.1
6	Deep gyp	5460	210	990	22	cde	15.0	1.1
7	Surface + deep gyp	5110	188	640	14	bcde	14.6	1.2
8	Surface gyp + deep rip	5330	188	860	19	cde	15.0	1.0
9	ES + surface gyp	5630	210	1160	26	e	14.9	1.0
10	Nutrient control	5340	210	870	19	bcde	14.8	1.1
11	Surface + deep OM	4390	210	-80	-2	abc	16.3	2.1
12	ES + OM	4570	210	100	2	abcde	17.0	3.1
13	All	4340	188	-130	-3	ab	17.1	2.2

* Treatments with the same letter do not significantly differ (P<0.05)

Forbes had no significant differences in canola grain yield, but the organic treatments did increase protein and reduce oil content (Table 5). The site was waterlogged for most of winter, and still had moisture in the profile at harvest, so any differences in plant available water capacity, or root penetration to depth, were unlikely to have shown up in this season. The plant population was also extremely variable due to the surface roughness from the ripping and waterlogging from 70mm of rain immediately after sowing. This variation has been included in the statistical analysis, but also suggests that small-seeded canola may not be the best crop for growing immediately after a ripping program.

Table 5. 2020 Grain yield (GY) for canola at Forbes

Trt		Yield	SE	Delta GY	Rel GY%	LSD*	Protein	Oil
1	Control	2470	194	0	0	ns	19.9	44.9
2	Shallow rip	2530	222	60	2	ns	19.9	44.3
3	Banded fert	3070	193	600	24	ns	20.3	43.9
4	Surface gyp + shallow rip	2710	192	240	10	ns	20.4	45.0
5	Deep rip	2680	176	210	9	ns	20.8	43.2
6	Deep gyp	2650	193	180	7	ns	21.4	42.7
7	Surface + deep gyp	3010	172	540	22	ns	20.6	43.7
8	Surface gyp + deep rip	2840	192	370	15	ns	20.4	44.0
9	ES + surf gyp	2700	193	230	9	ns	20.4	43.7
10	Nutrient control	2750	193	280	11	ns	20.2	44.2
11	Surface + deep OM	2630	173	160	6	ns	22.4	40.6
12	ES + OM	2570	192	100	4	ns	22.5	40.4
13	All	2590	192	120	5	ns	21.6	41.7

* Treatments with the same letter do not significantly differ (P<0.05). ns = not significant difference

Spring Ridge also had no significant differences in biomass at flowering, or barley grain yield (Table 6). The high yield reflects the good season in 2020 and suggests that the site may not be as constrained as originally thought. We are uncertain if this lack of observed yield constraint is long term, or due to the above average rainfall in early 2020 which may have resulted in short term leaching of the salinity found in the initial sampling.

Table 6. 2020 grain yield (GY) for barley at Spring Ridge

Trt		Yield	SE	Delta GY	Rel GY%	LSD*
1	Control	6520	226	0	0	ns
2	Shallow rip	6030	253	-490	-8	ns
3	Banded fert	6170	256	-350	-5	ns
4	Surface gyp + shallow rip	6410	254	-110	-2	ns
5	Deep rip	6320	256	-200	-3	ns
6	Deep gyp	6360	256	-160	-2	ns
7	Surface + deep gyp	6700	227	180	3	ns
8	Surface gyp + deep rip	6050	227	-470	-7	ns
9	ES + surf gyp	5760	256	-760	-12	ns
10	Nutrient control	6460	254	-60	-1	ns
11	Surface + deep OM	6170	256	-350	-5	ns
12	ES + OM	6270	254	-250	-4	ns
13	All	6310	227	-210	-3	ns

* Treatments with the same letter do not significantly differ (P<0.05) ns = no significant difference.

Conclusions

We present one year of results, after a very wet summer/autumn which allowed all plots to refill after treatment application except for the Talwood site which has been planted in mid-January 2021. The 2021 crop will give a better indication of long term effects of treatments, and (possibly) under more typical conditions. Increases in yield as a result of the ripping may also require extra nutrients to achieve the increased yield potential.

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Contact details

David Lester
Department of Agriculture and Fisheries Queensland, Toowoomba
PO Box 2282, Toowoomba, Qld 4350
Ph: 07 4529 1386
Email: david.lester@daf.qld.edu.au

Chris Guppy
University of New England, Armidale
Agronomy and Soil Science
Ph: 02 6773 3567
Email: cguppy@une.edu.au

KEY CONTACTS

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

NORTHERN REGION

TOOWOOMBA
214 Herries Street
TOOWOOMBA, QLD 4350

northern@grdc.com.au
P:+61 7 4571 4800

OPERATIONS GROUP

GENERAL MANAGER, APPLIED R&D (NATIONAL)
Peter Carberry
Peter.Carberry@grdc.com.au
M: +61 4 3861 6544

SENIOR REGIONAL MANAGER
Gillian Meppem
Gillian.Meppem@grdc.com.au
M: +61 4 0927 9328

CONTRACT ADMINISTRATOR AND PANEL SUPPORT
Tegan Slade
Tegan.Slade@grdc.com.au
M: +61 4 2728 9783

CONTRACT AND TEAM ADMINISTRATOR
Brianna Robins
Brianna.Robins@grdc.com.au
P: +61 7 4571 4800

APPLIED RESEARCH AND DEVELOPMENT GROUP

SENIOR MANAGER CROP PROTECTION (NATIONAL)
Emma Colson
Emma.Colson@grdc.com.au
M: +61 4 5595 8283

SENIOR MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS (NATIONAL)
Michael Bange
Michael.Bange@grdc.com.au
M: +61 4 4876 6881

MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS
Kaara Klepper
Kaara.Klepper@grdc.com.au
M: +61 4 7774 2926

MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS
John Rochecouste
John.Rochecouste@grdc.com.au
M: +61 4 7774 2924

MANAGER CHEMICAL REGULATION (NATIONAL)
Gordon Cumming
Gordon.Cumming@grdc.com.au
M: +61 4 2863 7642

CROP PROTECTION MANAGER
Vicki Green
Vicki.Green@grdc.com.au
M: +61 4 2904 6007

CONTRACT ADMINISTRATOR
Linda McDougall
Linda.McDougall@grdc.com.au
M: +61 4 7283 2502

GENETICS AND ENABLING TECHNOLOGIES GROUP

NATIONAL VARIETY TRIALS OFFICER
Laurie Fitzgerald
Laurie.Fitzgerald@grdc.com.au
M: +61 4 5595 7712

GROWER EXTENSION AND COMMUNICATIONS GROUP

SENIOR MANAGER EXTENSION AND COMMUNICATION (NATIONAL)
Luke Gaynor
Luke.Gaynor@grdc.com.au
M: +61 4 3666 5367

GROWER RELATIONS MANAGER
Richard Holzknecht
Richard.Holzknecht@grdc.com.au
M: +61 4 0877 3865

GROWER RELATIONS MANAGER
Graeme Sandral
Graeme.sandral@grdc.com.au
M: +61 4 0922 6235

COMMUNICATIONS MANAGER
Toni Somes
Toni.Somes@grdc.com.au
M: +61 4 3662 2645

BUSINESS AND COMMERCIAL GROUP

MANAGER COMMERCIALISATION
Chris Murphy
Chris.Murphy@grdc.com.au
M: +61 4 2277 2070

BUSINESS SUPPORT TEAM LEADER
Adam van Genderen
Adam.vangenderen@grdc.com.au
M: +61 4 2798 4506