WARRA
QUEENSLAND
FRIDAY 8TH
MARCH 2019

GRAINS RESEARCH UPDATE

DRIVING PROFIT THROUGH RESEARCH

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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GRDC Welcome

Welcome to the 2019 GRDC Grains Research Updates

Growers, advisers and industry stakeholders are constantly faced with challenges to farm profitability and productivity, which makes staying informed about the latest research and development outcomes a critical part of being in business.

Keeping growers and advisers informed is the key role of the annual Grains Research and Development Corporation (GRDC) Grains Research Updates, which are premiere events on the northern grains industry calendar and bring together some of Australia's leading grain research scientists and expert consultants.

For more than 25 years the GRDC has been driving grains research capability and capacity with the understanding that the continued viability of the industry hinges on rigorous, innovative research that delivers genuine profit gains. GRDC's purpose is to invest in research, development, and extension (RD&E) to create enduring profitability for Australian grain growers.

Despite the tough seasonal conditions currently being experienced across much of the Queensland and New South Wales grainbelts, the industry remains confident about the future and committed to learning more about innovation and technology and embracing practice change that has the potential to make a tangible difference to on-farm profits.

In response, this year's GRDC Grains Research Updates offer regionally relevant, credible and new science-based information covering priority issues like climate and environmental variability, new technology and market conditions to ensure growers and their advisers have up-to-date knowledge to make informed decisions on-farm.

So, I hope you enjoy the 2019 Updates and that the events provide an invaluable opportunity for learning, knowledge sharing and networking.

Luke Gaynor,

GRDC Senior Manager Extension and Communication

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GRDC Grains Research Update
WARRA

Friday 8th March, Warra Memorial Hall

Registration: 8:30am for a 9am start, finish 2.45pm

AGENDA		
Time	**Topic**	**Speaker(s)**
9:00AM	**GRDC welcome**	
9:10AM	**New frontiers in cereal breeding for a changing climate –** long coleoptile wheat, crop competitive varieties, new wheat types for late sowing windows & high temperature stress during grain fill.	*Greg Rebetzke (CSIRO)*
9:40AM	**The physiology & genetics of cold temperatures in chickpeas.**	*Neroli Graham and Annie Warren (NSW DPI)*
10:15AM	**Fungicide spray timing relative to inoculation –** how long do fungicides protect the crop from Ascochyta and is there usable kickback?	*Kevin Moore (NSW DPI)*
10:40AM	**Morning tea**	
11:10AM	**Chickpea harvest and desiccation timing impacts.**	*Richard Daniel (NGA)*
11:40AM	**The Helicoverpa resistance management strategy –** why, what it looks like, how is it working?	*Melina Miles (DAF Qld)*
12:05AM	**What we know/don't know about phytoplasma –** the link to puffy pod?	*Murray Sharman (DAF Qld)*
12:25PM	**Lunch**	
1:25PM	**Residual herbicides and sowthistle –** length of residual and efficacy.	*Michael Widderick and Andrew Erbacher (DAF Qld)*
1:55PM	**Deep P - Multi-year crop impacts and profit –** soil tests and process to pick where and when to apply deep-P profitably.	*David Lester (DAF Qld)*
2:10PM	**Grower experiences with deep P –** when, why, how and with what profit outcome?	*Ben Taylor ("Culara")*
2:25PM	**Discussion – nutrition for 2019**	
2:45PM	**Close**	

Contents

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New genetics to improve wheat establishment with deep sowing

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Key words

wheat, breeding, genetics, dwarfing genes, coleoptile length, establishment

GRDC code

CSP00199, CSP00200

Take home messages

- Current Australian wheat cultivars contain dwarfing genes that reduce coleoptile length by 40%. New dwarfing genes are available that reduce plant height but don't reduce coleoptile length.
- A gene increasing coleoptile length was identified and tagged with DNA markers. Breeding lines and DNA markers for new dwarfing and coleoptile length genes have been delivered to Australian breeders for efficient selection of improved crop establishment
- Deep-sowing studies in WA and NSW Managed Environment Facilities show benefit with new dwarfing and coleoptile length promoting genes in increasing emergence at sowing depths of up to 120mm but without changing plant height
- Moisture-seeking points coupled with new genetics should reliably allow seed placement and emergence from sowing depths of 100mm or greater, and/or with warmer soils

Background

In rainfed environments typical of the eastern and southern wheatbelts, crops are typically sown on the first breaking rains but sometimes moisture accumulated through summer is too deep for sowing with conventional variety × drilling systems. Key to good leaf area development for tillering, growth and weed competitiveness is good crop establishment. An ability to establish wheat crops from seed placed 80mm or deeper in the soil would be useful in situations where the subsoil is moist but the surface dry. Seeding onto moisture at depth extends the opportunities for a greater portion of the cropping program to be sown in the traditional sowing months of May and June or earlier in April following summer rain. A separate but concerning issue is the influence of increasingly warmer soil temperatures on reductions in coleoptile (the shoot that grows from the seed and allows seedling emergence through the soil) length. Earlier sowing into warmer soils will reduce coleoptile length by as much as 60% so that a variety such as Mace with a 75mm coleoptile at 15°C will likely have a 40mm coleoptile at 25°C soil temperature. Some seed dressing and pre-emergent herbicides will reduce this coleoptile length even further to affect establishment.

The green revolution *Rht-B1b* and *Rht-D1b* dwarfing genes reduced plant heights to reduce lodging and increase grain yields and so are present in most wheat varieties worldwide. Their presence also reduces the length of the coleoptile by as much as 40%. This reduces crop emergence when sown at depths greater than 50mm, tiller number and leaf size to reduce water-use efficiency and weed competitiveness.

New dwarfing genes

A range of alternative dwarfing genes have been identified in overseas wheats with potential to reduce plant height and increase yields while maintaining longer coleoptiles and greater early vigour. Some of these genes (e.g. *Rht8* and *Rht18*) have been used commercially overseas but have not been assessed for use here in Australia. We reduced the larger global set of alternative dwarfing genes to *Rht4, Rht5, Rht8, Rht12, Rht13* and *Rht18*, and then developed linked DNA-markers to assist with breeding of these genes in a commercial breeding program. Separately, we then bred these genes using conventional and DNA-based methods into the old, tall wheat variety Halberd for testing and disseminating to Australian wheat breeders.

Genes that promote coleoptile growth

While switching to new dwarfing genes will remove the growth inhibition on early growth, there is a need to promote coleoptile growth, particularly in the presence of conventional dwarfing genes. A gene with major effect on coleoptile length was identified in current wheat cultivars. Through a GRDC funded project, we demonstrated that the gene not only increased coleoptile length but also emergence with deep sowing in field trials conducted over three years at Yanco NSW (Figure 1). The gene was tagged with molecular markers and tested in a wide range of Australian wheat germplasm. We estimated that only 10% of recently released cultivars carry the coleoptile growth promoting gene. The markers were distributed to Australian breeding companies to assist with the selection and the expected increase of gene frequency in future cultivars. Additional genetic variation for coleoptile length and early growth exists in elite germplasm. For breeders to take full advantage of this variation, additional genes controlling this trait need to be identified and tagged with markers for efficient selection and combining growth promoting genes for even better performance.

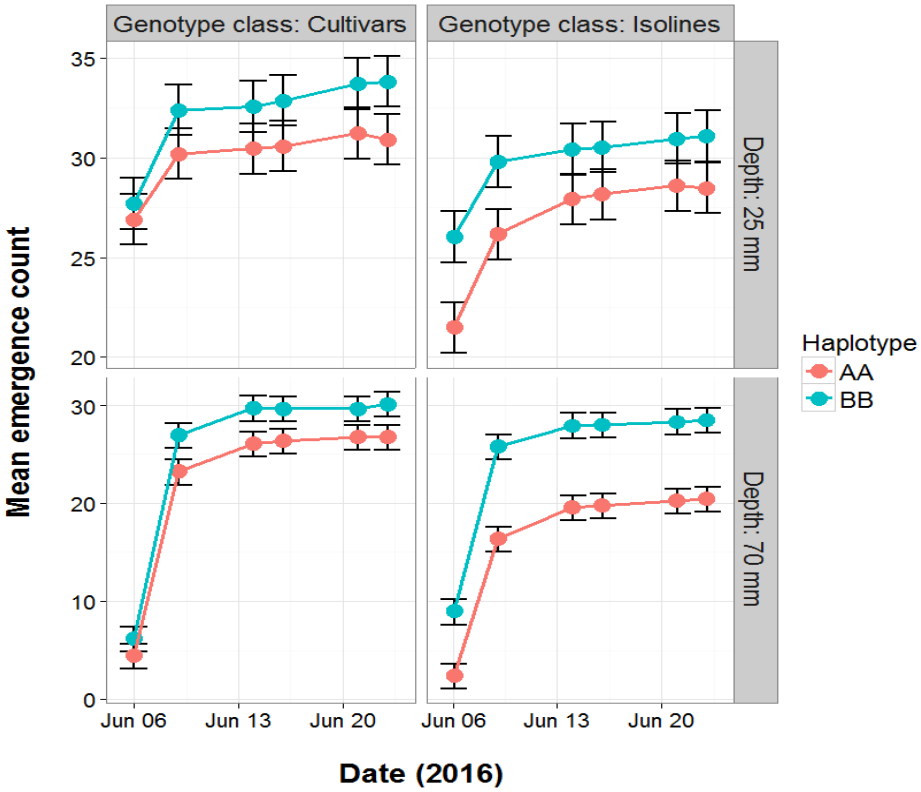

Figure 1. Emergence of wheat cultivars carrying conventional dwarfing genes and tall isolines in Young background in the NSW MEF at Yanco in 2016. Sowing depth treatments were 25 mm and 70 mm depth. 12 cultivars and 12 isolines were grouped according to the presence of the coleoptile length promoting gene (BB, long coleoptiles) and the lack of the gene (AA short coleoptiles).

Preliminary sowing depth field studies

Field studies have commenced on these Halberd-based dwarfing gene lines and show that lines containing these genes produced coleoptiles of equivalent length to Halberd (up to 135mm in length; Figure 2) and established well when sown at 100mm depth in deep sowing experiments conducted at Mullewa and Merredin in 2016 (Figure. 3). Grain yields of lines containing the new dwarfing genes were equivalent to the yields of lines containing the commonly used *Rht-B1b* and *Rht-D1b* dwarfing genes while previous studies have shown the new dwarfing genes were linked to greater grain yields when sown deep owing to greater plant number with improved establishment.

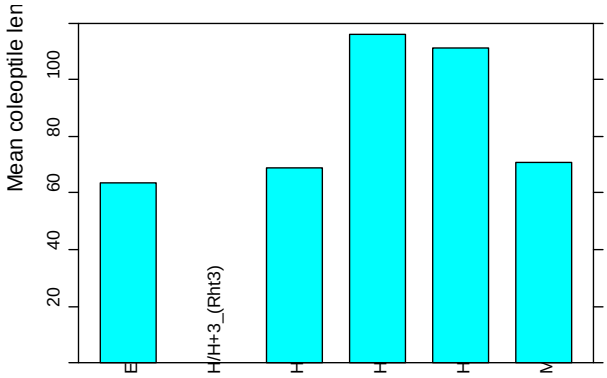

Figure 2. Coleoptile lengths of a tall wheat genotype (Halberd) and genotypes with dwarfing genes *Rht-B1b (syn. Rht1)* and *Rht8* in a Halberd background. Emu Rock and Mace are current commercial cultivars with *Rht-B1b* and *Rht-D1b*, respectively.

The most likely useful new dwarfing genes, *Rht13* and *Rht18*, have been bred into a range of current commercial wheats (Figs 4 and 5). Long coleoptile wheat breeding lines in Mace, Scout, Espada, EGA Gregory and Magenta have been delivered to Australian breeders for testing and use in breeding. If there are no problems with these new dwarfing genes, we may see the first of the long coleoptile wheat varieties in 3-4 years in NVT testing!

Agronomic opportunities

Although there is real promise in the new genetics, there is significant opportunity in coupling new genetics with new existing seeding technologies. Deep sowing is an issue overseas and in the eastern Australian states. The availability of moisture-seeking points commonly used elsewhere should allow the reliable placement of seed at depths of 100mm or greater. These points produce a slot deep into the soil at the base of which a seed is sown at 10-50mm depth. That said, further research is required aimed at tools and methods assessing across different moisture-seeking points to optimise seed placement at depth across a wide range of soil types.

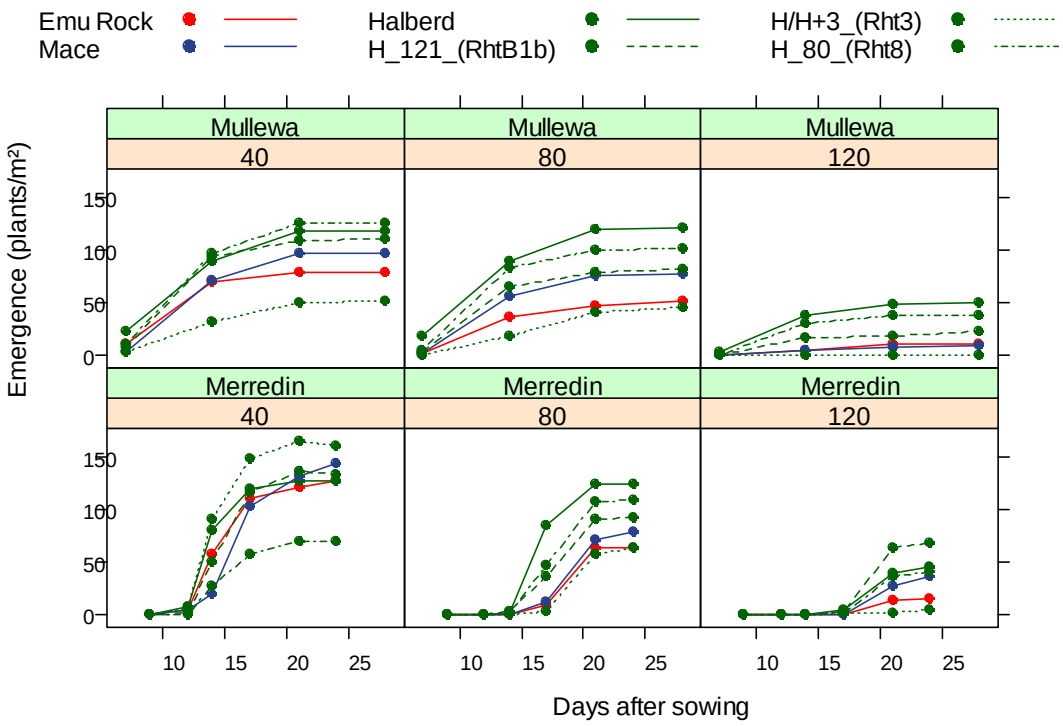

Figure 3. Patterns of emergence of wheat genotypes with different dwarfing genes sown at target depths of 40, 80, or 120 mm at Mullewa and Merredin in 2016 (after French *et al.* 2017).

Summary

Wheat breeders now have the new dwarfing genes to breed longer coleoptile wheat varieties. Genes that increase coleoptile length have also been identified and tagged with markers. These genes are expected to play an important role in improving emergence from depth in the presence of conventional dwarfing genes. Matching new genetics with appropriate agronomy and technologies should ensure the emergence and establishment of deep-sown wheats particularly when sown early to make use of summer rains sitting deep in the soil profile or to increase sowing opportunities in the traditional months of May and June.

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Supplementary images

Figure 4. Wheat variety Mace(b) (left) side-by-side with long coleoptile, Mace(b) containing the *Rht18* dwarfing gene (right) at Condobolin in 2017.

Figure 5. Wheat variety EGA Gregory(b) (left) side-by-side with long coleoptile, EGA Gregory(b) containing the *Rht18* dwarfing gene (right) at Condobolin in 2017.

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The physiology and genetics of cold temperatures in chickpeas – what do we know and where is the research heading?

Annie Warren, Neroli Graham, Rosy Raman and Kristy Hobson,
NSW Department of Primary Industries

Key words

chilling tolerance, early flowering, *Cicer arietinum*, breeding, prebreeding

GRDC code

BLG111

Take home messages

- During flowering, chickpeas are sensitive to cold (< 15°C) temperatures which cause flower abortion and results in a delay between flowering and pod onset
- While early sowing has the potential to reduce the risk of terminal drought, it moves the flowering window to cooler temperatures
- Current work aims to identify new sources of chilling tolerance for chickpea variety development and to assess the suitability of elite breeding lines for flowering and podding during cool conditions

Introduction

Chickpeas are well adapted to the northern cropping region in Australia and provide a valuable, economically sound, broadleaf rotation in our farming systems. However, various biotic and abiotic factors cause actual yields to fall between 1.7–2.7 t/ha below potential yield across the region (Yield Gap Australia, 2018). Cold temperatures during the flowering window can significantly reduce crop yield through delaying and interrupting pod set, causing loss of early pods. In 2016, agronomists estimated yield losses due to cool spring temperatures in north-west NSW ranged from 0.5–0.7 t/ha. Chickpeas can suffer damage during the flowering window from both frosts, when temperatures fall below -1.5°C, and "chilling" where average day temperature does not exceed 15°C. In this paper, we will focus on chilling temperatures and their impacts on flowering and podding.

While cool spring temperatures have been historically avoided through late sowing, changes to our farming systems mean there is a greater need for flexibility to sow chickpeas earlier to increase subsequent cropping options and to avoid heat and terminal drought at the end of the season. This however, pushes the flowering window to coincide with cooler ambient temperatures. In north west NSW (Tamworth region), average daily temperatures are not consistently above 15°C until late September and in the cool 2016 season, average temperatures remained below the critical temperature until late October (Figure 1). In addition, short bursts of cool temperatures occurring weeks after temperatures have begun to rise can interrupt pod and seed set even in areas that generally experience warm spring temperatures.

This paper outlines current knowledge of chickpea's physiological response to cool temperatures during flowering and what opportunities and challenges exist for improving chilling tolerance through breeding and variety selection.

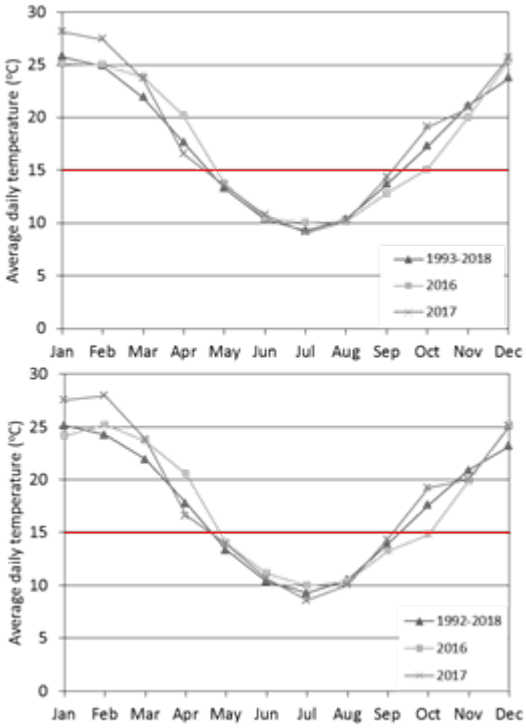

Figure 1. Average daily temperature for Tamworth (top) and Dubbo (bottom) shows cool spring conditions can continue into late September and October

The story so far

Early sown chickpeas consistently suffer from an extended gap between commencement of flowering and first pod appearance. In ideal conditions, chickpeas will produce pods within a couple of days of flowering (Clarke & Siddique, 1998). However, under cool conditions, the time from the beginning of flowering to the first pods appearing can be more than 2 months if temperatures remain consistently cool (Berger et al., 2005). At Warwick, early flowering genotypes took more than 30 days to begin podding when average temperature after flowering did not exceed 14.4°C (Berger et al., 2004). While the length of time between flowering and pod initiation varies across locations and between varieties, the delay in podding remains closely linked to temperature (Berger et al., 2004; Berger et al., 2005; Berger et al., 2012). For every degree drop in average daily temperature between 14 and 10°C, the time between flowering and podding is extended 12 days (Berger et al., 2005). During this time plants may continue to produce flowers that are subsequently aborted, or may cycle back into and out of a vegetative state.

While chickpeas may continue flowering under cool conditions, most flowers are subsequently aborted rather than producing pods. In their work with early sown chickpea in Western Australia, Siddique and Sedgley (1986) found only 38% of flowers carried through to produce harvestable pods among early sown plants, compared to 83% in later sowings. This difference was largely due to flower abortion at low temperature – up to 800 flowers/m^2 were aborted when average daily temperature was below 15°C, but no flower abortion occurred once temperature rose above this critical value (**Table 1**).

Siddique and Sedgley observed that although early sown crops suffer a high flower abortion penalty, this does not necessarily result in inferior yields when compared to later sown crops. Despite high flower abortion, the earliest sown chickpeas still produced the greatest yield. Across 72 genotypes and 5 locations, Berger et al. (2004) found early flowering cultivars were consistently the highest yielding, especially in locations that suffered end of season drought. Flower abortion under cool

temperatures therefore constitutes a significant lost opportunity, as early flowering plants that also set pods early have the greatest potential to produce high yields.

Table 1. Effect of cool temperatures at 50% flowering on flower abortion at Merredin, Western Australia 1983

Planting date (1983)	Mean Daily temperature (°C) at 50% flowering	Aborted flowers (m^{-1})
May 17th	12.5	800
May 31st	13.6	500
June 14th	14.7	200
June 30th	16.8	0
July 20th	17.7	0

Note: Modified from Croser et al., 2003

On the small scale…

Cool temperatures reduce pollen vigour and ovary and style size of chickpea flowers, alterations that have been implicated in reduced flower fertilisation and increased flower abortion (Srinivasan et al., 1999). Pollen development and function is affected by cool temperature from the early stages of pollen production from 9 days before anthesis through to pollen tube growth and ovary fertilisation (Figure 2). Cold spells during key points in pollen development at either 9 or 4–6 days prior to anthesis can reduce pod set by 30–60% in susceptible varieties (Clarke & Siddique, 2004). Cool temperature may also decrease the quantity of pollen reaching the flower stigma due to reduced pollen release from anthers as well as a reduction in ovary and style size (Srinivasan et al., 1999). The resulting mismatch increases the difficulty of pollen transfer from anther to stigma (Srinivasan et al., 1999). Once pollen reaches the stigma, pollen germination can be reduced by 30% in susceptible varieties, although some susceptible varieties exhibit normal pollen germination (Clarke & Siddique, 2004; Srinivasan et al., 1999).

Once pollen has germinated on the stigma, pollen tube growth is particularly sensitive to cool temperatures. As a result, far fewer pollen tubes reach the ovary for fertilisation. Srinivasan et al. (1999) found while 100% of flowers at an average temperature of 20°C had pollen tubes reach the base of the style, as few as 23.5% of flowers at 10°C had more than 10 fully grown pollen tubes 1 day after flower opening. This resulted in fertilization of as few as 8% of flower ovules. In highly susceptible varieties, no pollen tubes will reach the ovary within 24 hours of pollen germination under cool conditions (Clarke & Siddique, 2004). As average day temperature increases from 5°C to 25°C, rate of pollen tube growth increases exponentially with only marginal increases in growth rate between 5–15°C (Srinivasan et al., 1999). Knowledge about these specific impacts of cool temperatures on chickpea reproduction have led to development of breeding practices such as pollen selection (Clarke et al., 2004) that are better able to target chilling tolerance.

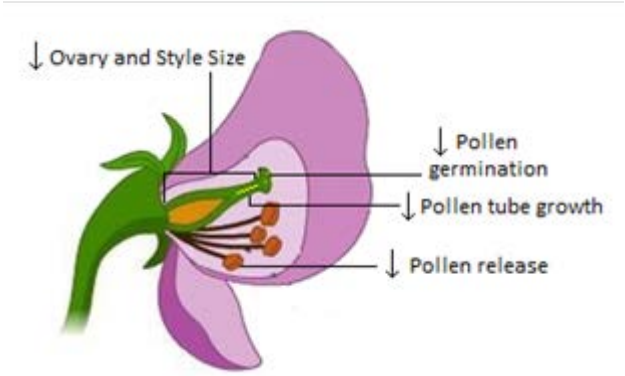

Figure 2. Impacts of cool temperature (< 15°C) on male and female reproductive organs of chickpea flowers

Note: Modified from Science Learning Hub – Pokapū Akoranga Pūtaiao (2011)

Opportunities for breeding chilling tolerant varieties

While cool temperature during flowering is a relatively new issue for the northern region, it has been identified as yield limiting across southern and western Australia since the early introduction of the crop. As a result, significant work has been conducted in Western Australia to develop chilling tolerant material for breeding programs. Clarke et al. (2004) developed two chilling tolerant cultivars, Rupali and Sonali, that could produce pods at 10–12°C and as result pod 20–27 days earlier than existing Western Australian varieties. However, these cultivars have insufficient disease resistance and do not yield comparably to the best yielding varieties in the northern region (K.Hobson, *pers comm*). In addition, time from flowering to podding can range from 30–70 days at temperatures ranging from 10–12°C (Berger et al., 2005). While not suited to northern environments, both Rupali and Sonali have been included in the northern breeding program since 2011 in an attempt to produce well adapted varieties with the ability to set pods at lower ambient temperature. However, the chilling tolerance during flowering and early pod set of progeny derived from either Rupali or Sonali has been insufficient to confer a significant improvement in the ability to set pods early under cool temperatures.

Limited genetic variation within domesticated chickpea restricts further progress in producing cultivars capable of podding at low temperature. However, some wild relatives of chickpea show considerably greater chilling tolerance and are able to set pods within 20 days of the beginning of flowering under cool temperatures, compared to the best chickpea cultivar doing so at 30 days (Berger et al., 2005). While chickpea pod production is reduced by 3–5 times when plants are kept at an average temperature of 10°C compared to 19°C, one particularly promising accession of *Cicer echinospermum* showed no reduction in pod set, setting more than 6 times the number of pods compared to chickpea at the lower temperature (Berger et al., 2012). There is, therefore, potential to include hybrids between chickpea and its wild relatives in breeding programs to make faster progress towards varieties that produce pods and seeds under suboptimal temperatures.

Where are we now?

Current research aims to identify useful sources of tolerance to suboptimal temperatures that can be used in breeding programs to improve future varieties. In Western Australia, both collections of chickpea and wild relatives are being screened by researchers at CSIRO as potential new sources for chilling tolerance during the early reproductive phase. Since current methods for identifying chilling tolerant chickpea lines is an expensive and labour-intensive process, several projects are working on developing tools to streamline identification of chilling tolerant breeding lines. At the University of Western Australia, Dr J Croser and her team are working to improve controlled environment screening for chilling tolerance amongst a wide set of chickpea genotypes. The underlying genetics

of early flowering and chilling tolerance in chickpea during flowering is being investigated by NSW DPI at Wagga Wagga and Tamworth to improve knowledge about genetic control of early flowering and podset to potentially work towards developing genetic markers. This project uses a set of recombinant inbred lines formed from hybridisation between domestic chickpea and the wild relative *Cicer echinospermum* which were observed to flower and pod comparatively early in 2016.

In northern and southern NSW, current varieties and elite breeding lines are being assessed for flowering and pod set characteristics under cool spring temperatures through manipulation of sowing date. The aim of this work is to; quantify yield loss from cool temperatures during flowering in the northern and southern NSW regions, expand knowledge of drivers that may improve chilling tolerance, and identify future breeding directions. In 2018, field trials were conducted to benchmark current varieties and identify breeding lines with potential superior chilling tolerance when compared to existing varieties in northern environments. Data collected from the 2018 season is currently being processed for analysis.

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The authors would like to thank Helene Davidson and Jessica Simpson for their assistance with data collection and trial management at the Tamworth and Wagga Wagga field sites in the 2018 chilling tolerance work.

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Chickpea Ascochyta research: what if I miss a spray – are there salvage options with new chemistry; how long do fungicides persist?

Kevin Moore, Steve Harden, Kristy Hobson and Sean Bithell, NSW DPI, Tamworth, NSW

Key words

chickpea, Ascochyta, management, fungicide persistence, missed spray, fungicide kickback

GRDC code

Grains Agronomy & Pathology Partnership - A strategic partnership between GRDC and NSW DPI (DAN00213)

Take home messages

- Follow latest advice for managing Ascochyta - applying fungicides before rain is a key component of this advice
- Chlorothalonil and mancozeb fungicides are persistent and rain fast (up to 50mm rain in 10 minutes)
- If you miss an Ascochyta fungicide spray, research indicates salvage sprays with new chemistry may be an option within tight timeframes, but this requires field confirmation
- Do not rely on salvage fungicide sprays as part of your 2019 Ascochyta management plan – aim to spray crops prior to rainfall events.

Background

Traditional chickpea Ascochyta blight fungicides e.g. chlorothalonil and mancozeb need to be applied before rain because they are protectants only. However, new chemistry and formulations offer the possibility of limited salvage fungicide options for Ascochyta if applied soon after infection (rainfall) events. Efficacy of these fungicides is far more reliable when applied prior to an infection event. Prophylactic use of efficacious fungicides applied prior to infection events, is and should remain the bedrock of Ascochyta management plans.

Likely scenarios when a preventative i.e. pre-rainfall, fungicide application is missed are:

- rain occurs when it was not predicted
- un-availability of spray contractors
- machinery breakdowns before or during application
- insufficient time to spray entire chickpea crop prior to rain.

This paper summarises recent research that shows chickpea Ascochyta blight may be able to be controlled if a pre-rainfall fungicide application is missed.

2017 Tamworth chickpea Ascochyta salvage spray field trial (FUN17)

The aims of this trial were to (i) evaluate efficacy of applying fungicides to a crop in which Ascochyta had established and (ii) to determine if newer fungicides had any 'kickback' activity when applied after a rain event.

Treatments

1. Nil (tap water)
2. Aviator Xpro® @ 400 mL/ha in 100 L/ha water backpack (registered but restrictions on number of applications per season and stage of crop development); no claim for kickback activity. Actives: 75g/L bixafen + 150g/L prothioconazole
3. Unite 720® @ 1000 mL/ha in 100 L/ha water backpack (registered); no claim for kickback activity. Active: 720g/L chlorothalonil
4. Veritas® @ 1000 mL/ha in 100 L/ha water backpack; no claim for kickback activity. Active 200g/L tebuconazole + 120 g/L azoxystrobin (registered, but restrictions on number of applications per season)

Operations

Kyabra(D) sown 30 May 2017, seed treated P-Pickel T, plots 4 m x 11 m; 4 reps as a randomised complete block (RCB)
Inoculated 14 Jul in rain (15.2mm)

Post-inoculation rain and spray applications

14 Jul	15.2 mm
20 Jul	2.0 mm
4 Aug	20.0 mm
3 Sep	3.0 mm
5 Sep	1st sprays 41hr post rain
14 Sep	8.0 mm
18 Sep	1st Ascochyta scores

Methodology

Ascochyta was deliberately allowed to establish in the trial to provide high disease pressure under which to test the aims of the trial. Ascochyta was established by spraying the trial during a rain event with a suspension of Ascochyta inoculum containing 483,333 conidia/mL at a water rate of 100L/ha. This resulted in uniform infection ie every plant in the trial developed Ascochyta. High disease pressure was favoured further by waiting for three more infection cycles (rain events on 20 Jul, 4 Aug and 3 Sep) before applying the first fungicide sprays on 5 Sep. Ascochyta was scored on 18 Sep by assessing each plot on a scale of 1-5 where 1 = least disease and 5 = most disease.

Key findings

Aviator Xpro and Veritas reduced Ascochyta compared with Unite 720 and the nil control (Table 1). There was no difference in control of Ascochyta between Aviator Xpro and Veritas. Unite had no post-infection efficacy on Ascochyta. The lower Ascochyta score compared with the control in Table 1 reflects the prophylactic activity from the application on the 5th of September for the 14th of September infection event.

The best management recommendation for Ascochyta control remains that fungicide should be applied prior to forecast rain to provide the greatest level of protection. Post-infection sprays should not be a planned part of your standard Ascochyta management plan.

Table 1. Ascochyta (AB) severity score (1-5) on Kyabra(b) chickpeas sprayed with Aviator Xpro, Veritas, Unite or Water (Nil) 41 hours after rain started in 2017 Tamworth field trial (FUN17)
F pr AB<0.001; l.s.d AB Score = 0.884; AB score 1 = least disease, 5 = most disease

Treatment	Rate/ha	Mean AB Score (18 Sep 2017)
Aviator Xpro	400 mL	1.75
Veritas	1000 mL	1.75
Unite	1000 mL	3.00
Nil (water)	Water only	5.00

2018 Tamworth chickpea Ascochyta salvage glasshouse experiments

Two glasshouse experiments were conducted in 2018 to provide additional evidence to support the 2017 field trial, FUN17.

Experiment 1 (FUN18GH)

In the first replicated experiment, chickpea plants (cv Kyabra(b)) with 4-5 nodes were inoculated with Ascochyta twice to optimise infection. Plants were allowed to dry for 30- 60 minutes between 1st & 2nd inoculations. The rate was 8.3 x 10^5 conidia/mL applied to run-off and incubated in a rainfall simulator.

Twenty-four (24 hr) or 48 hours after inoculation, treatments of Unite 720 @ 1000 mL/ha, Aviator Xpro @ 400mL/ha, Veritas @ 1.0L/ha were applied with a water-only treatment as the nil control. The plants were placed under glasshouse conditions conducive to Ascochyta development (23C, 80% RH).

Only Aviator Xpro and Veritas stopped Ascochyta development and they did so at both application times. Unite 720 (chlorothalonil) had no post inoculation activity - there was just as much Ascochyta with the Unite 720 treatments as with the Nil water control. All reps of the Unite 720 and Nil treatments had maximum Ascochyta disease score of 5 (on 1-5 scale); the other treatments all scored 1 (no disease).

Trial results indicate Aviator Xpro and Veritas provided control of Ascochyta blight infections when applied 24 and 48 hours post- infection.

Experiment 2 (FUN18GH)

In the second experiment, Aviator Xpro @ 400 mL/ha and Veritas @1000 mL/ha were applied to Kyabra(b) chickpeas with 14 nodes at four times: 24, 48, 72 and 96 hours after inoculation with a water-only treatment as the Nil control.

Inoculation, incubation and experimental conditions were as for experiment 1. The number of petioles, leaves and stems with at least one Ascochyta lesion were counted 14 days after inoculation. Data was analysed using the glmer function from the R package lme4; means were compared by the Tukey method.

Ascochyta developed on all tissues at all times in the Nil water control (Tables 2-4). No Ascochyta developed on any tissue when Aviator Xpro or Veritas were applied 24 or 48 hrs after inoculation and very little or none developed when Aviator Xpro or Veritas were applied 72 hrs after inoculation (Tables 2-4). However, applying Aviator Xpro or Veritas 96 hrs after inoculation did not stop

Ascochyta with no significant difference in numbers of petioles, leaves or stems with Ascochyta between these fungicides applied at 96 hrs after inoculation and the Nil control (Tables 2-4).

Table 2. Number of petioles with Ascochyta at 14 days after inoculation on chickpeas sprayed with Aviator Xpro, Veritas or water (Nil) 24, 48, 72 and 96 hours after inoculation

Tissue & treatment	24h	48h	72h	96h
Petiole Aviator Xpro	0.0	0.0	0.25a	4.75b
Petiole Veritas	0.0	0.0	0.50a	5.50b
Petiole Nil	7.5	7.0	7.50b	7.25b

numbers followed by the same letter are not significantly different within timings, P =0.05

Table 3. Number of leaves with Ascochyta at 14 days after inoculation on chickpeas sprayed with Aviator Xpro, Veritas or water (Nil) 24, 48, 72 and 96 hours after inoculation

Tissue & treatment	24h	48h	72h	96h
Leaf Aviator Xpro	0.00	0.0	0.25a	4.25b
Leaf Veritas	0.00	0.0	0.75a	5.25b
Leaf Nil	8.75	9.0	8.00b	6.50b

numbers followed by the same letter are not significantly different within timings, P =0.05

Table 4. Number of stems with Ascochyta at 14 days after inoculation on chickpeas sprayed with Aviator Xpro, Veritas or water (Nil) 24, 48, 72 and 96 hours after inoculation

Tissue & treatment	24h	48h	72h	96h
Stem Aviator Xpro	0.0	0.0	0.25	3.75a
Stem Veritas	0.0	0.0	0.00	4.50a
Stem Nil	6.0	7.5	6.50	5.75a

numbers followed by the same letter are not significantly different within timings, P =0.05

The results of the 2018 glasshouse experiments looking at the impact of Ascochyta infection period prior to application of Aviator Xpro and Veritas need to be validated in field trials.

However, the results indicate if growers wait 72 hours after rain starts before spraying, Ascochyta may still develop and if they wait to 96 hours they will not stop the disease.

If a pre-rainfall spray is missed, one management option available to growers may be to apply Aviator Xpro (before late flowering (BBCH 69) with a maximum of two sprays during the season) or Veritas (may be applied twice in a season, with no restriction on use at flowering).

However, growers are encouraged to implement the current recommended management practice of applying before rain.

2007 Tamworth chickpea Ascochyta fungicide rain fastness experiment

This replicated experiment was designed to answer a question many agronomists and growers have asked i.e. “Yesterday, I sprayed my chickpeas with an Ascochyta fungicide and today it rained - is my crop still protected?”

Chickpeas cv Jimbour with 3-5 nodes were sprayed with Bravo® (720g/L chlorothalonil), Dithane™ Rainshield™ (750g/kg mancozeb) or water (Nil fungicide). Fungicides were applied with a backpack at standard rates ie Bravo @ 1000 mL/ha or Dithane Rainshield @ 2kg/ha in 100L/ha water by

placing pots on ground and walking at 6.0 km/h. As soon as the fungicides had dried, the plants were placed in a rainfall simulator and exposed to 50mm, 100mm or 150mm of 'rain' at a rate of 50mm per 10 minutes; plants not exposed to rain were the Nil rain (Dry) control. After exposure, plants were inoculated with Ascochyta, placed in a humid chamber for 48 hours and assessed 10 days later.

Bravo was very rain fast – 150mm rain in 30 min did not appear to reduce efficacy compared with 50mm in 10 min.

Dithane Rainshield was not as rain fast with 150 mm having significantly more stem lesions than 50mm. However, it's highly unlikely a chickpea crop in southern Australia would ever be exposed to 50mm rain in 10 min (the lowest intensity we could get with this simulator).

So, the answer to the growers' questions is "Yes – your crop is still protected, although new growth emerging post-fungicide is not".

2018 Tamworth chickpea Ascochyta fungicide persistence glasshouse experiment

A glasshouse experiment was conducted to determine how long a fungicide protects tissue to which it has been applied. Fungicides (Unite 720 @ 1000 mL/ha, Aviator Xpro @ 400 mL) were applied once to Kyabra or PBA Seamer with 4-5 nodes and inoculated with Ascochyta 1, 2 or 4 weeks later; water was the Nil control. New growth was removed every 2-3 days to remove tissue that had not been sprayed from the experiment. Ascochyta was assessed on petioles, leaves and stems on a 1-9 scale where 1= nil disease and 9 = tissue dead. The data was analysed using the lme function of the R package nlme.

The findings were similar for petioles, leaves and stems. No Ascochyta developed on either variety with Aviator Xpro at any time of inoculation. There was little or no disease with Unite 720. For the Nil control, Kyabra had more Ascochyta than PBA Seamer and disease scores tended to be lower for later inoculation.

This experiment supports previous research that showed chickpea Ascochyta fungicides provide lasting protection for the tissues to which they have been applied.

Chickpea Ascochyta management in 2019

The current recommendation for cost-effective management of chickpea Ascochyta includes:

- Treat all planting seed with a registered fungicide, applied properly. Seed treatment protects against seed transmitted Ascochyta, Botrytis and a range of opportunistic soil fungi that can attack seedlings if seed has lower vigour, is planted deep or if conditions don't favour rapid emergence e.g. cold, wet soil, herbicide residues.
- Paddock selection – avoid planting chickpeas in the same paddock for at least 3 years. Avoid planting chickpea immediately next to last year's chickpea crop.
- Grow varieties with the highest level of Ascochyta resistance suitable for your area
- For NSW and southern QLD, in high risk Ascochyta situations i.e. paddocks that had chickpeas in 2016, 2017 or 2018, apply a preventative fungicide before the first post emergent rain event
- In central QLD, where the Ascochyta risk is lower compared to southern regions, grow the highest yielding varieties but have in place an Ascochyta plan. In most seasons in CQ, there will be no cost benefit of applying a fungicide before Ascochyta is detected. When conditions do favour Ascochyta, a reactive foliar fungicide program and protective pod sprays are warranted. Monitor the crop 10-14 days after each rain event.

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The impact of harvest management in chickpeas

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Key words

chickpea desiccation, harvest losses, grain quality

GRDC code

NGA00004: GRDC Grower Solutions for northern NSW and southern Qld

Take home messages

- Across 9 trials, there was no impact on yield or grain quality from any registered harvest management option, when applied ~2 weeks prior to anticipated harvest
- All treatments increased leaf discolouration and leaf drop, however the clearest differences were observed in impact on stem dry down
- The most effective treatments for stem dry down were the mixture of Weedmaster® ARGO® + Ally® or the mixture of Gramoxone® 250 + Sharpen WG®
- Decisions on harvest management choice should be determined by cost, attitude to Ally plant back restrictions, weed spectrum present at harvest and speed of desiccation required
- There was no indication that any harvest management treatment increased the level of screenings when assessed with the slotted screen size used for defective grain assessment. However, when crop harvest was delayed by ~14 days, grain moisture was significantly reduced and screenings were increased, even in the untreated plots
- Application of Reglone® or Gramoxone 250 at less mature crop stages (~3 weeks prior to anticipated harvest) resulted in a significant reduction in both yield (~10%) and test weight (2-3kg/hL)
- Large levels of grain losses were measured at the header front in small plot trials (~200 kg/ha) with no indication of any shattering or pod drop prior to harvest
- Large levels of grain losses were also measured at the header front in a commercial case study (~160 kg/ha). These losses were primarily intact pods and losses were reduced by ~50% when harvested with the air front turned on
- Further research into improving harvest management of chickpeas appears warranted.

Background

In recent years, chickpeas have transitioned from being generally considered a rotation option between cereal crops to becoming a 'pillar' crop of the northern farming system. Historically, harvest management has fitted around the cereal harvest rather than being specifically driven by maximising the chickpea return. An improved understanding of the impacts of harvest management may enable improved financial returns or avoid significant losses.

NGA are currently involved in two aspects of harvest management evaluation; trials conducted during 2017 and 2018 to help improve the understanding and impact of current crop desiccation tools and in 2018, initial activity to evaluate the impact of desiccation timing and delayed harvest on crop yield, quality and harvest losses.

Chickpea desiccation evaluation 2017

An evaluation of desiccation options was conducted at five sites. Application at each site was when crops were estimated (by the grower or agronomist) to be ~2 weeks prior to harvest. Table 1 shows

key details from these trials. NB harvest was delayed at some sites during to rain events after desiccation.

Table 1. Product evaluation trials 2017

Location	Variety	Date of application	Harvest date	Days before harvest
Warra	PBA Seamer(b)	10/10/2017	14/11/2017	35
Pittsworth	PBA Seamer(b)	20/10/2017	10/11/2017	21
Pallamallawa	PBA HatTrick(b)	18/10/2017	1/11/2017	14
Bellata	PBA Seamer(b)	3/11/2017	16/11/2017	13
Mullaley	PBA Seamer(b)	3/11/2017	27/11/2017	24

Chickpea Desiccation evaluation 2018

A second season of product evaluation was conducted in 2018. Application timing was planned for a crop stage with ~85-90% of pods mature. Table 2 shows key details from these trials.

Table 2. Product evaluation trials 2018

Location	Variety	Date of application	Crop stage at application	Harvest date	Days before harvest
Warra	PBA Seamer(b)	2/11/2018	85% pods mature	16/11/2018	14
Mt Tyson	PBA HatTrick(b)	30/11/2018	91% pods mature	11/12/2018	11
Tulloona 1	PBA HatTrick(b)	26/10/2018	82% pods mature	12/11/2018	17
Tulloona 2	PBA Seamer(b)	23/10/2018	92% pods mature	7/11/2018	15

Trial Results 2017

All treatments improved % leaf discolouration and leaf drop compared to the untreated but generally with only minor differences between treatments.

A 'twist test' assessment was conducted to evaluate stem dry down. This assessment was designed in an attempt to provide an objective 'harvest readiness' measure. Tested 10 plants/plot. Each plant was evaluated separately using a double twist motion. Data was recorded as the % of plants where stems snapped following the twist test.

Yield, grain moisture and protein were assessed at all sites. Test weight and screenings were evaluated at 3 sites. Screenings were assessed using a 4 mm slotted screen as an indication of % defective grain.

Figure 1 shows the combined analysis from all sites for the twist tests conducted 10-17 days after application.

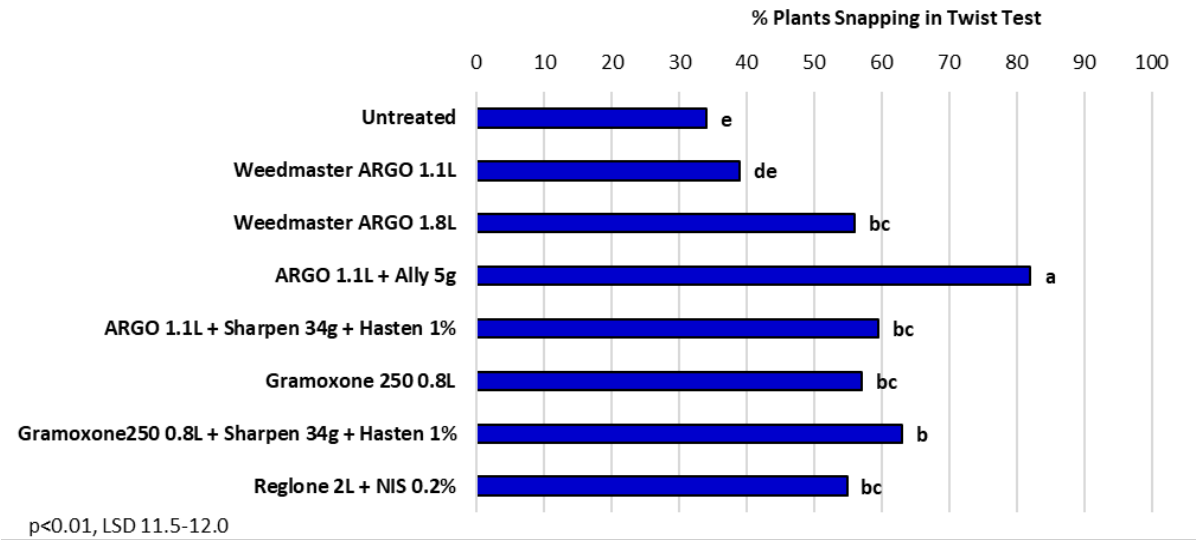

Figure 1. Stem twist test results 10-17 days after application, as an indication of stem dry down. *(Mean of 5 trials 2017)*

NIS = non-ionic surfactant

Trial results 2018

Assessment of leaf discolouration showed similar patterns to 2017, however the magnitude of difference between treatments and the Untreated was reduced. No treatment provided any significant improvement in leaf drop compared to the Untreated. A twist test assessment was again conducted. All trials were harvested with yield and grain quality assessed at all sites.

Figure 2 shows the combined analysis from all sites for the twist tests conducted at 7-15 days after application.

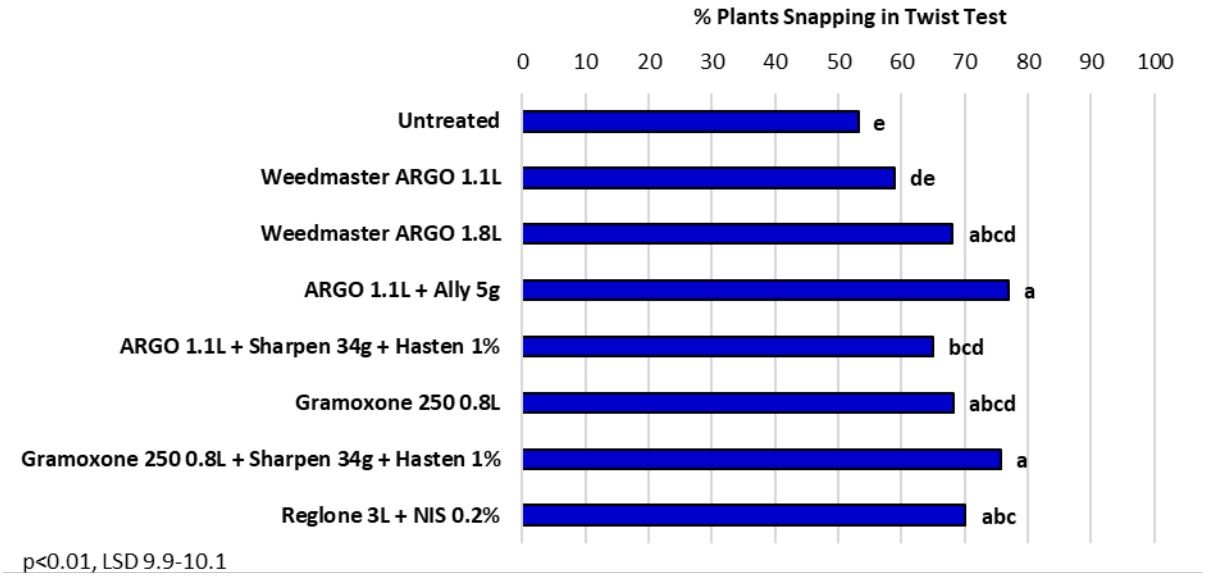

Figure 2. Stem twist test results 7-15 days after application, as indication of stem dry down. *(Mean of 4 trials 2018)*

NIS = non-ionic surfactant

Key Points 2017 and 2018

Leaf discolouration and drop

- All treatments increased % leaf discolouration and % leaf drop but without consistent differences between treatments
- Improvements in % leaf discolouration and % leaf drop compared to the Untreated were greater in 2017, where high levels of October rainfall encouraged crop regrowth.

Stem dry down

- Similar patterns of performance were seen in both seasons, however the differences between treatments were reduced in 2018
- The most effective options for stem dry down were either the mixture of Weedmaster ARGO + Ally or the mixture of Gramoxone 250 + Sharpen
- There was a dose response to glyphosate with increased stem snapping from the 1.8 L/ha rate
- There was no consistent difference between Weedmaster ARGO 1.8L, Gramoxone 250 or Reglone alone, or the mixtures of Sharpen with either Weedmaster ARGO or Gramoxone 250

Yield and grain quality

- There was no significant difference in yield recorded in any of the 9 trials
- There was no significant difference in test weight or % screenings in any of the 9 trials.
- Similar patterns were observed for grain % protein
- There was no significant difference in grain moisture in 8 of the 9 trials. Grain moisture was ~8-10% in Untreated grain in these trials
- However all harvest management treatments reduced grain moisture by ~1% in a 2017 trial where regrowth had been evident and the Untreated grain was ~13% moisture. There was no difference between harvest management treatments in this trial.

Overall

- Harvest management treatments increased both chickpea leaf and stem desiccation but had no impact on crop yield or grain quality. (It should be noted that the use of desiccants is not recommended when the grain is destined for use as seed, as germination % can be affected.)

Desiccation and harvest timing evaluation 2018

Field observations in 2017, suggested significant chickpea yield losses can occur when harvest of ripe crops is delayed. (This was supported by observations from QDPI agronomist Mike Lucy in the early 2000's). A series of split plot trials were designed to evaluate a combination of desiccant product and application timing combined with harvest timing.

Trials were conducted in commercial crops with desiccation targeted to commence when the crop was ~3 weeks prior to harvest with separate applications at both 2 and 1 week prior to expected harvest. The same treatments were applied with harvest delayed by ~2 weeks. The first application was designed to evaluate the impact from an application where crop maturity was considered 'immature'. (NB: at Tulloona 2 the first application was delayed and was only ~2 weeks prior to commercial harvest. It was hoped the second timing would be close to current commercial recommendations with a final 'conservative' timing.)

Pod maturity was assessed at each application on 10 main branches per plot. Pods were considered mature when a 'yellow beak' was starting to extend on the enclosed grains. This stage often corresponded with a purplish tinge appearing on the pod coat. Table 3 shows the key trial details.

Table 3. Desiccation and harvest timing impact 2018

Location	Variety	Dates of application	Crop stages at application	Harvest dates	Days before harvest
Warra	PBA Seamer(ⓑ	19/10/2018 2/11/2018 9/11/2018	52% pods mature 85% pods mature 90% pods mature	1. 16/11/2018 2. 30/11/2018	28/14/7 42/28/21
Tulloona 1	PBA Seamer(ⓑ	16/10/2018 26/10/2018 5/11/2018	58% pods mature 83% pods mature 88% pods mature	1. 12/11/2018 2. 27/11/2018	29/17/7 44/33/22
Tulloona 2	PBA HatTrick(ⓑ	18/10/2018 23/10/2018 30/10/2018	82% pods mature 91% pods mature 100% pods mature	1. 7/11/2018 2. 20/11/2018	20/15/8 33/28/21

NB: the Tulloona 2 site was a late replacement and was only ~ 2 weeks prior to harvest at the first application timing. Tulloona 1 and 2 used different varieties than assessed in the product evaluation project.

Trial results

Assessment of leaf discolouration and leaf drop were conducted, however the main focus was impact on yield from varied desiccant application timings and the impact from harvest delay. Consistent small plot header settings were attempted but environmental and other conditions varied between harvest dates.

Application timing

- Desiccant applications ~prior to the industry standard recommendation of <15% green pods present in chickpeaswith Gramoxone 250 or Reglone significantly reduced test weight (by ~2-3 kg/hL) and grain yield by ~10% (~120 kg/ha)
- However, there was no impact on % protein, % moisture or % screening from any product

Harvest timing

- Inconsistent results were observed on the impact of harvest timing on yield:
  - A significant reduction in yield was measured at Tulloona 1 (by 28% or ~300 kg/ha) when harvest was delayed by 15 days
  - No difference at Tulloona 2
  - A significant increase was measured at Warra (by 13% or ~130 kg/ha) when harvest was delayed by 14 days. NB High levels of harvest losses occurred at this site, particularly from the first harvest.
- Grain moisture was significantly lower at the delayed harvest timing when analysed over all trials
- There was a significant increase in % screenings (increased from 7 to 11%) at the delayed harvest timing in all individual trials, with no significant product impact.

Harvest losses

An assessment of harvest loss was conducted at all sites. Pre-inspection showed there was no shattering loss of grain or pod drop prior to either harvest. Individual grain, pods and splits were counted together with the number of grain/pod and grain weight.

Two types of harvest loss were assessed. 'header front' losses were pods or grain that did NOT physically get into the header for processing and were found where the crop had been harvested but before any losses from the back of the header.

Losses were also assessed directly behind the header. These losses were the combination of any header front loss plus the 'header processing' loss. The difference between the two was the amount of grain that was lost over the sieves. This loss is largely determined by the header set-up.

Small plot headers were used in all trials. Increased header processing losses are likely compared to commercial headers, however header front losses would generally be considered low due to operation speed and the ability to harvest at very low heights.

- There was no evidence of any pod drop or shattering loss prior to either harvest timing
- Header front losses (grain or pods 'lost' at the front of the header) averaged ~100 grains/m^2 (~200 kg/ha)
- In these 3 trials, the header front losses represented an extra ~15-20% of harvested yield

Commercial harvest loss evaluation 2018

Commercial observations and comments indicated that high levels of header front loss of grain and pods were also being experienced, particularly in crops with reduced height or yield potential. Commercial scale data was generated at one site where an air front was in operation on a crop of PBA Seamer(b).

Replicated areas were assessed where the only difference was whether the air front was operating or turned off. Individual grain, pods and splits were counted together with the number of grain/pod and grain weight. Harvest monitor estimates indicated the yield ranged from ~0.5 to 1.0 t/ha.

- When the air front was turned OFF, header front losses were ~160 kg/ha (~$135/ha). This was the equivalent of ~15-30% of the harvested yield
- When the air front was turned OFF, ~90% of the header front losses were intact pods (~145 kg/ha)
- When the air front was turned ON, the header front losses were reduced by ~80-90 kg/ha (saving ~$70-75/ha)
- Header front losses were ~85% of the total grain losses i.e.: the header processing losses were ~25 kg/ha

Conclusions

The comparison of registered harvest management options in chickpeas has shown no impact from any option on crop yield or grain quality when products are applied at currently recommended crop maturity stages.

However, application on less mature crops, particularly with desiccants such as diquat or paraquat, are likely to reduce yield with grain test weight also impacted in these trials. There was however no indication that desiccation treatments were having an impact on screening levels.

The clearest difference in product performance was observed in the stem dry down 'twist test' where the addition of Ally to glyphosate or Sharpen to paraquat resulted in the largest % of plants with dry stems. These treatments may provide a benefit in situations where stem dry down is of concern and likely to cause harvest difficulties.

The level of header front grain losses is of concern and warrants more detailed evaluation than conducted in this initial activity. Although these losses may have been more evident in 2018 due to lower yielding and possibly poorer feeding crops, a better understanding of header management appears warranted. In the commercial case study, a benefit of $70-75/ha was achieved by the use of an air front.

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Helicoverpa armigera resistance management in pulses, and recent research findings on Rutherglen bug

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Key words

Helicoverpa armigera, resistance, chickpeas, mungbeans, soybeans, Rutherglen bug, canola

GRDC code

DAQ00196, UM00048 (NIRM)

Take home messages

- The *H. armigera* resistance management strategy is designed to prolong the useful life of the newer chemistry currently available to pulse growers. Familiarise yourself with the strategy and the full range of options available for *Helicoverpa* control in chickpeas, mungbeans and soybeans. Consider what products you will use if a second spray is required in these crops
- Rutherglen bug adults are present in canola crops much earlier than was previously thought. Females are depositing eggs in the soil and leaf litter from early spring through to harvest. At this point, there is no obvious option for preventing the build-up of large populations of nymphs in canola stubble, but recent work is helping to understand how these populations develop.

The *Helicoverpa armigera* resistance management strategy (RMS)

This material has been extracted from the "Science behind the strategy" document available at https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/

General rationale for the design of the strategy

Chickpeas and mungbeans are currently, and for the foreseeable future, the most valuable grains crops influenced by the RMS. Therefore, the resistance management strategy (RMS) is primarily focused on insecticide Modes of Action (MoA) rotation in these systems and is built around product windows for Altacor® and Steward® because:

1. Altacor® (chlorantraniliprole) is at risk from over-reliance in pulses, but resistance frequencies are currently low.
2. Steward® (indoxacarb) is at risk due to genetic predisposition (high level genetic dominance and metabolic mechanism) and pre-existing levels of resistance in NSW and QLD (with elevated levels in CQ during 2016-17). In addition, the use of indoxacarb in pulses may increase as generic products come on to the market.

There are two regions within the RMS, each with their own resistance management strategy designed to make the most effective products available when they are of greatest benefit, whilst minimising the risk of overuse:

1. Northern Grains Region: Belyando, Callide, Central Highlands & Dawson (Table 1)
2. Central Grains Region: Balonne, Bourke, Burnett, Darling Downs, Gwydir, Lachlan, Macintyre, Macquarie & Namoi (Table 2)

- The RMS provides windows-based recommendations common to these regions because *H. armigera* moths are highly mobile and have the capacity to move between these regions.

- No RMS is currently proposed for the Southern and Western grain regions (Victoria, South Australia and Western Australia) for winter crops. Biological indicators suggest that that the risk of *H. armigera* occurring in winter crops, at densities where control failures may occur, is presently considered low. *Helicoverpa* control in summer crops in these regions should use the Central Grains region RMS.

Use of broad-spectrum insecticides

The early use of synthetic pyrethroids (SPs) in winter pulses (August – early September) is adopted where the assumption is made that early infestations of *Helicoverpa* will be predominantly *H. punctigera* which are susceptible to SPs. Similarly, the use of carbamates to delay the application of Group 28 or Group 6 products, carries risks. If adopting this strategy, be aware of the following risks:

- Recent monitoring with pheromone traps has shown *H. armigera* to be present in all parts of the Northern Grains region from early August (www.thebeatsheet.com.au)
- Reduced efficacy of SPs and carbamates against *H. armigera* can be masked when treating very low population densities (< 3/sqm)
- If *H. armigera* are present, even at low levels in a population treated with SPs or carbamates, the treatment will select for further resistance. Whilst initial applications may be effective, later treatments may be significantly less effective.
- treatments may be significantly less effective.

Table 1. Grains resistance management strategy for *Helicoverpa armigera* across Australia. Best practice product windows and use restrictions to manage insecticide resistance in *H.armigera.* **Northern Region: Belyando, Central Highlands, Dawson and Callide.**

Increasing ↑ SELECTIVITY ↓ Decreasing

Insecticide	June				July				Aug				Sept				Oct				Nov				Dec				Jan				Feb				Mar				Apr				May			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Bacillus thuringiensis																																																
Helicoverpa viruses																																																
Paraffinic oil (Note 1)																																																
Chlorantraniliprole (Note 2, 3)																																																
Indoxacarb (Note 4)																																																
Spinetoram (Note 2, 4, 5)																																																
Emamectin benzoate (Note 2, 4, 5)																																																
Carbamates (Note 2, 4 6)																																																
Pyrethroids (Note 2, 4, 7)																																																

No restrictions	DO NOT USE during this period	No more than one application per crop per season	No more than two applications per crop per season

ADDITIONAL INFORMATION

Notes:

1. Some nC27 paraffinic spray oils can be used to suppress Helicoverpa populations and are best used as part of an IPM program.
2. Observe withholding periods (WHP). Products in this group have WHP 14 days or longer.
3. Maximum one spray of chlorantraniliprole alone or in mixtures per crop per season.
4. Refer to label for warning of insecticide risk to bee populations.
5. Maximum two consecutive sprays alone or in mixtures per crop per season.
6. MODERATE RESISTANCE IS PRESENT IN *H.ARMIGERA* POPULATIONS – FIELD FAILURES LIKELY.
7. HIGH RESISTANCE IS PRESENT IN *H.ARMIGERA* POPULATIONS – FIELD FAILURES EXPECTED!

Table 2. Grains resistance management strategy for *Helicoverpa armigera* across Australia. Best practice product windows and use restrictions to manage insecticide resistance in *H.armigera.* **Southern QLD, Central & Northern NSW Regions: Balonne, Bourke, Burnett, Darling Downs, Gwydir, Lachlan, Macintyre, Macquarie & Namoi.**

SELECTIVITY: Increasing ↑ / Decreasing ↓

Insecticide	June				July				Aug				Sept				Oct				Nov				Dec				Jan				Feb				Mar				Apr				May			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Bacillus thuringiensis																																															
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Pyrethroids (Note 2, 4, 7)																																															

No restrictions | **DO NOT USE during this period** | **No more than one application per crop per season** | **No more than two applications per crop per season**

ADDITIONAL INFORMATION

Notes:

1. Some nC27 paraffinic spray oils can be used to suppress Helicoverpa populations and are best used as part of an IPM program.
2. Observe withholding periods (WHP). Products in this group have WHP 14 days or longer.
3. Maximum one spray of chlorantraniliprole alone or in mixtures per crop per season.
4. Refer to label for warning of insecticide risk to bee populations.
5. Maximum two consecutive sprays alone or in mixtures per crop per season.
6. MODERATE RESISTANCE IS PRESENT IN *H.ARMIGERA* POPULATIONS – FIELD FAILURES LIKELY.
7. HIGH RESISTANCE IS PRESENT IN *H.ARMIGERA* POPULATIONS – FIELD FAILURES EXPECTED!

Table 3. Explanatory notes for product windows in all regions

Insecticide	Number of insecticide windows	Duration of insecticide windows	Maximum number of applications/crop/season
Chlorantraniliprole (Altacor®)	2	10 weeks	1
• 10 week windows restrict selection to a maximum of 2 consecutive generations of *H. armigera* (includes 2-3 weeks residual beyond the end of each window i.e. 12-13 weeks total exposure). • Start date of first window correlates well with historical data relating to average daily temperatures that result in early pod-set. • Exposure of 2 consecutive generations is off-set by long non-use periods (8 weeks in southern/central region and 18 weeks in northern region). • Use is not recommended in spring mung beans as there is less likelihood of both *H. armigera* and bean pod borer being present.			
Indoxacarb (e.g. Steward®)	Northern - 3 Central - 2	6 weeks	1
• 6 week windows restrict selection to a single generation of *H. armigera*. • Each window is followed by a non-use period of a minimum of 6 weeks. • Indoxacarb is an important early season rotation option for chickpeas and faba beans, and provides a robust selective alternative to Altacor® when Helicoverpa pressure is high.			
Bacillus thuringiensis	1	Season long	No restrictions
Helicoverpa viruses			No restrictions
Spinetoram (e.g. Success Neo®)*			2
• Low resistance risk and not widely used.			
Emamectin benzoate (e.g. Affirm®)*	1	Season long	2
• Very low resistance frequency and not used widely. • However, emamectin benzoate is a good option for rotation to spread resistance risk away from Altacor®. • BUT industry needs to become more confident with using this product for it to be of value in resistance management.			
Carbamates	1	Season long	1
Synthetic pyrethroids			
• *H. armigera* resistance is present at moderate to high levels, but one strategic application per season in regions where *H. punctigera* predominates in early spring may be effective. • Carbamates are a rotation tool for indoxacarb and Altacor® either early season in chickpeas or late season in mungbean.			

*Resistance monitoring for selective products is a key component of the RMS and changes in resistance frequencies will result in the introduction of product windows for those insecticides not currently windowed.

The number of uses in the RMS is more restrictive than stated on the Altacor® label, why?

To avoid repeated use of either Steward® or Altacor® within the use window, the number of allowable applications is 1 per crop. In some instances, the label registration may allow for more than one application; the recommendations were developed in consultation and supported by the chemical companies. It is anticipated that changes to product labels will follow to ensure consistency between labels and the RMS.

Does the RMS impact on recommendations for insecticide use in cotton and other crops?

The RMS is not intended to compromise the ability of the cotton industry to use any products registered for *Helicoverpa* in Bollgard® cotton. This is because selection for insecticide resistance is considered low due to the high likelihood that survivors of conventional sprays used in Bollgard cotton would be killed by Bt toxins expressed in plants. For further information go to: http://www.cottoninfo.com.au/publications/cotton-pest-management-guide.

Similarly, the RMS does not attempt to align the use of the Group 28s in mungbeans and chickpeas with use in other grain crops or horticulture. To do so would add a level of complexity that would make the RMS impractical.

Shouldn't other modes of action (MoA) be windowed to prevent the potential development of resistance to these products?

There is little evidence to suggest that other products should be windowed now to slow the development of future resistance. Both Affirm® (emamectin benzoate) and Success Neo® (spinetoram) show no sign of reduced susceptibility in testing (L. Bird, CRDC data). This result is consistent with the relatively limited use of these products in the grains industry to date. If a shift in susceptibility is detected in future testing, it is the intention that the product/s will be windowed to limit selection pressure.

The SPs and carbamates are not windowed because there are already well established, relatively stable moderate-high levels of resistance to these MoAs and limiting their use will not change this situation.

By restricting the use of just the 'at risk' products, keeping the RMS as simple as possible, and allowing maximum choice of registered products, we anticipate that the grains industry will be more inclined to use the RMS.

What is the relative efficacy of the 'softer' options for Helicoverpa control in mungbeans and chickpeas?

In 2017, QDAF entomology undertook a number of trials to compare the knockdown/contact efficacy, and residual efficacy (persistence in the crop) of Altacor®, Steward®, Affirm® and Success Neo®. The purpose of these trials was to provide agronomists and growers with information on how well each of the products worked, and to provide confidence to use another option, rather than relying solely on the Group 28 products.

The results show that these products are equally effective on 3rd, 4th or 5th instar larvae that receive a lethal dose of the product – as would be achieved with good spray coverage (Figure 1a). However, there is considerable benefit in products persisting in the crop to control larvae that may hatch after the spray, or emerge from flowers, buds or pods where they may have been protected from an earlier application. The long residual efficacy of Altacor ® has been a major factor in its popularity. The data in Figure 1b shows the relative efficacy of these products from 0 – 20 days after treatment in the field (at 5-day intervals).

For more information on the relative performance of these products in terms of feeding potential and recognising larvae affected by the different insecticides, see recent articles on the Beatsheet blog (https://thebeatsheet.com.au/).

Figure 1 a. Efficacy of insecticides on medium - large Helicoverpa larvae (diet incorporated bioassay)

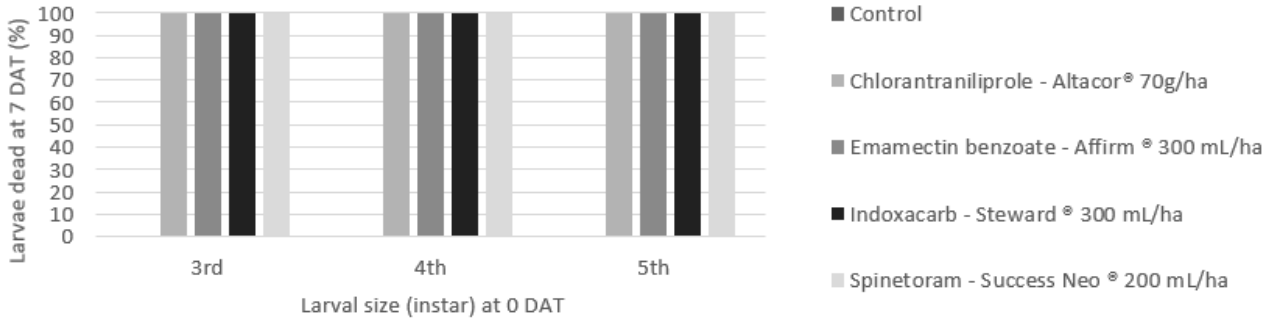

Figure 1 b. Assessment of mortality made at 7 days after exposure to treated foliage.
2nd-3rd instar larvae fed on treated foliage for 48 hours before being transfered to diet.
Chickpea foliage (field crop) sprayed at 0DAT and then harvested for trial at 0, 5, 10, 15, 20 days after spraying

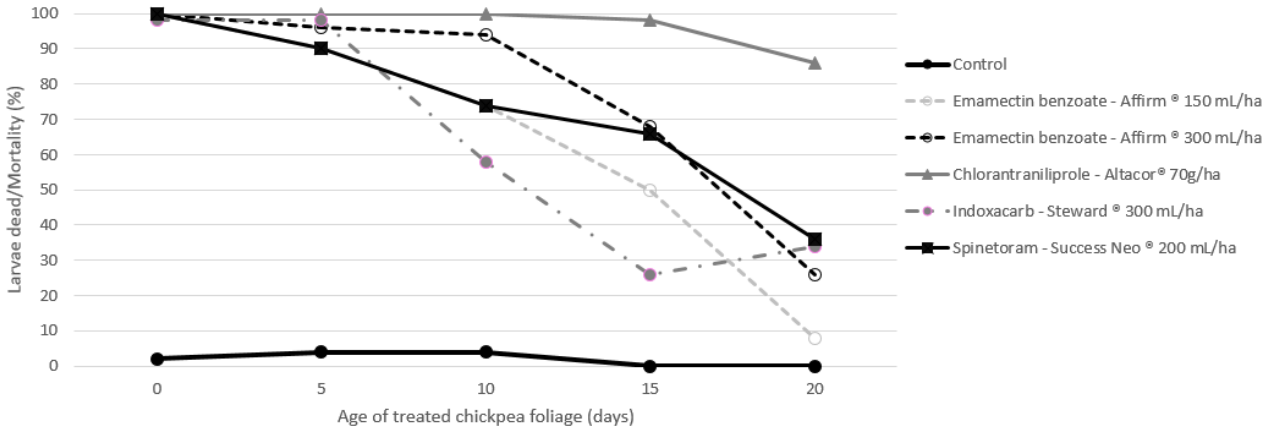

Figure 1. Relative efficacy (a) direct contact and (b) residual, of softer options for Helicoverpa control in chickpea and mungbean crops.

Nucleopolyhedrosis virus (NPV) – an option for some pulses?

Along with the conventional chemistry options discussed above, NPV may also be an option for reducing selection pressure on Helicoverpa, particularly in pulses. In 2017, QDAF Entomology looked at the potential to use NPV with repeated application of lower rates. Low rates of NPV do not pose a resistance risk as there is no risk of resistance developing to NPV – it is a disease, not a chemical. The opportunity that presents is to include NPV with fungicide applications in chickpeas, faba beans, lentil and field peas. The concept is that by supressing the Helicoverpa population during the vegetative and flowering stages, the density will stay below threshold through pod fill – or at least delay the build-up of a damaging population. In 2017, there was little need for repeated fungicide applications in chickpea because it was dry, so in the trial we applied 2 applications of NPV about 2 weeks apart. The NPV-treated plots sustained lower populations and did not exceed threshold (3.5 larvae/m^2 in this instance) for the duration of the crop (Figure 2). The strategy for deploying NPV effectively requires additional investigation, as does the potential loss that may accumulate from sustained sub-threshold populations which may result from this approach.

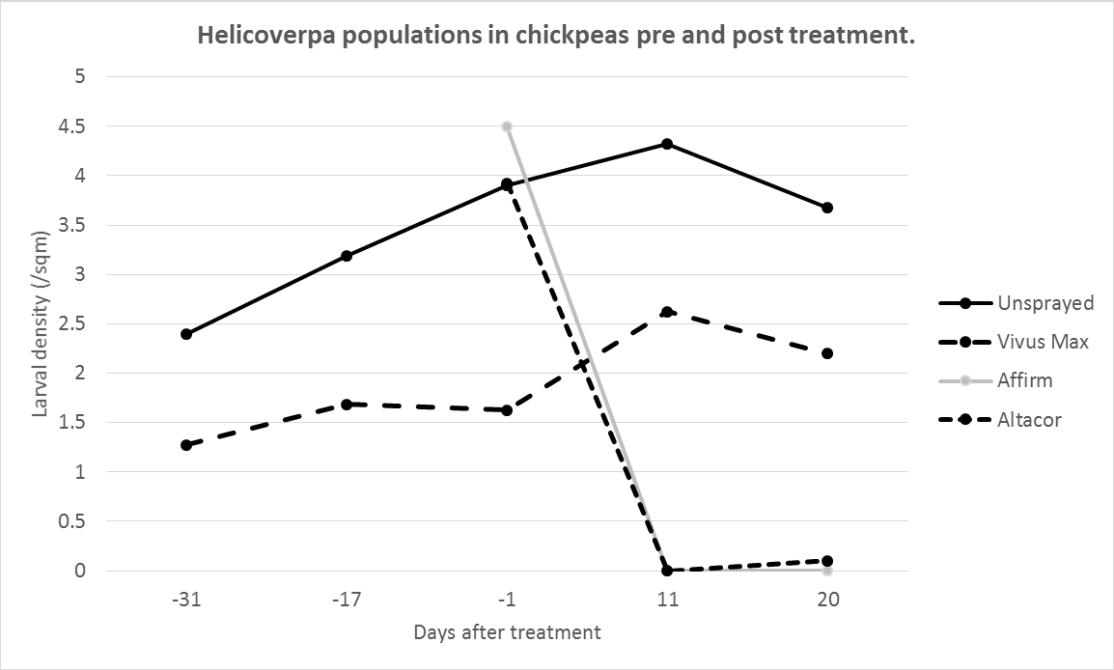

Figure 2. Helicoverpa population density in chickpeas treated twice (day -31 and day -17) with low rate NPV. Affirm® and Altacor® were applied when the Helicoverpa density reached threshold in the untreated plots.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

Information on the *H. armigera* RMS is extracted from material prepared by NIRM to support the implementation of the RMS. The authors acknowledge the contribution of NIRM members to the development of this material. The authors also acknowledge CRDC's investment in the long-term screening of Helicoverpa resistance to conventional chemistry which has informed the development of the RMS.

We are grateful to the growers who allow us access to their farms and crops, and to the agronomists who assist us in locating potential field sites. We also thank the many growers and agronomists who share with us their experiences and insights into the issues they face and the practicalities of the management options we propose.

Reference

NIRM (2018) Science behind the Resistance Management Strategy for *Helicoverpa armigera* in Australian grains. https://ipmguidelinesforgrains.com.au/ipm-information/resistance-management-strategies/

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Phytoplasma in grain legumes: what we know / don't know

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Key words

mung bean, mungbean, peanut, groundnut, chickpea, soybean, phytoplasma

GRDC code

DAQ00186 – Improving grower surveillance, management, epidemiology, knowledge and tools to manage crop disease

DAN00202 - New tools and germplasm for Australian pulse and oil seed breeding programs to respond to changing virus threats

Take home messages

- Phytoplasma has caused significant losses in grain legume crops, is widespread in the northern region and infects a wide range of hosts
- Many things remain unknown. A leafhopper vector is suspected but not confirmed
- Monitor surrounding weeds for phytoplasma symptoms and maintain good farm hygiene to reduce risk of spread into crops
- Growers should monitor crops for leafhopper activity and phytoplasma infection and report any outbreaks to Qld DAF entomologists and/or pathologists.

In recent years there have been outbreaks of phytoplasma in a number of grain legume crops throughout the northern region. Phytoplasma are specialised bacteria that infect the phloem cells of plants and are spread from plant to plant by insect vectors, such as leaf hoppers. Symptoms are variable and depend on the crop type and timing of infection. In severely affected plants, which are infected prior to flowering, symptoms generally include stunting with masses of small cupped leaves (little leaf) that either do not flower or display phyllody - when flower structures turn green and leafy and pods are either not present or are sterile (Figure 1). Plants infected after flowering often have normal growth lower on the plant, followed by masses of deformed flowers and small pods that remain green, fail to produce harvestable seed or have damaged seed.

Phytoplasma disease outbreaks have been common and widespread in mung bean (*Vigna radiata*) crops and other crops including soybeans (*Glycine max*), peanuts (*Arachis hypogaea*) and pigeon pea (*Canjanus cajan*), both in the late spring plantings of 2016, and in early 2017 plantings. Mung bean crops were affected in all major production areas in early 2017 from locations such as Ayr, Capella, Kingaroy, Dalby, St George, Inverell, Gurley, Wee Waa and Narrabri - spanning a distance of over 1,200 km from north to south (Figure 2). Many mung bean crops in the Dalby region had greater than 40 % disease incidence and up to 70 % from a crop in Capella in central Queensland. Losses were estimated at $800,000 in that season. At the same time, phytoplasma outbreaks also occurred in horticultural crops from several locations in eastern Australia. Although we have found phytoplasma in a wide range of weed hosts, we do not yet know if one or more of these are critical in the disease cycle that leads to disease epidemics in nearby crops.

A devastating disorder of several soybean crops from the Cecil Plains region in late autumn 2016 was also associated with phytoplasma infection. Affected plants produced no, or very few filled pods,

and instead, had a proliferation of tiny immature pods as shown in Figure 3. Affected plants also remained green while unaffected crops nearby matured and browned off as expected. Significant losses were sustained by the growers with almost 100% of plants affected in some paddocks on a couple of farms, with virtually no yield and estimated losses of $400,000 on each farm.

We are continuing to confirm associations of phytoplasma infection with unusual pod and seed symptoms. It appears that strange fruit symptoms such as puffy pod in mungbeans (Figure 4) or shrivelled, discoloured seeds in peanuts (Figure 5) and chickpeas (Figure 6) are associated with phytoplasma infection. To date, 49 peanut plants with shrivelled kernels (typical of "peanut kernel shrivel - PKS" disorder) have all tested positive for phytoplasma and have also had some degree of leaf symptoms typical of phytoplasma. While there may be additional causes of shrivelled kernels in peanuts, our testing has not yet found similar peanut plants (i.e. with shrivelled kernels) without phytoplasma infection. Losses due to PKS have been estimated by the Peanut Company of Australia to be in the order of $1 million during the worst years. Also, a loss of confidence among Bundaberg peanut growers due to PKS has limited new peanut expansion in recent years, which represents an opportunity cost of several million dollars.

A similar story is emerging for puffy pod symptoms in mung beans with all 13 plants tested so far with typical puffy pod symptoms, testing positive for phytoplasma. Our testing will need to be done over more than one season and from various locations to increase our confidence that phytoplasma is strongly linked to these fruit symptoms, but also to investigate if there may be other possible causes in the absence of phytoplasma.

There are many different phytoplasmas that can affect crops. Therefore, we aimed to determine the identification of the phytoplasma present. We also determined the geographical extent of disease and the host range, as this may provide evidence of hot spots of disease and possible associations to key weed hosts surrounding crops. To investigate the identification and diversity of phytoplasmas present we studied the P1/P7 region of the 16S gene from more than 23 crop and weed hosts from a wide geographical range from far north QLD to northern NSW. Partial genome sequence indicates there are two species of phytoplasma in crops and weeds, *Candidatus* Phytoplasma aurantifolia and *C.* Phytoplasma australiense. The vast majority of samples were from the *C.* Phytoplasma aurantifolia group which has been previously reported in Australia from pigeon pea (*Canjanus cajan*) and stylosanthes.

A known vector of phytoplasma, the phloem-feeding brown leaf hopper (*Orosius orientalis*, Figure 7), was collected from some affected mung bean crops but it is not certain that it was associated with these disease outbreaks. We are currently developing and validating rapid molecular assays to identify potential vector species and determine if they are carrying the phytoplasma pathogen. However, at this stage we have not confirmed the insect vector responsible for transmission of phytoplasma into the affected crops.

To our knowledge, these have been the most significant, widespread outbreaks of phytoplasma in broadacre crops to occur in this region of Australia. It is unclear what the underlying reasons are for this sudden increase in disease incidence in recent years. In 2018, the incidence of disease did reduce compared to previous years, but was still present in most summer legume crops inspected. Prior to the succession of outbreaks in recent years, phytoplasma infection is estimated to have only occurred on average at a very low incidence (usually much less than 1%) and often not at all in most crops. One reason for the great increase in disease in some seasons could be that spring rains favour weeds that carry the phytoplasma and host the putative vector (leafhopper). It is also possible that the phytoplasma may be vectored by another insect (most likely within the Cicadellidae family).

There was a mild, wetter winter in 2016 followed by a dry spring. We suspect that these conditions were favourable for the phytoplasma and vector to survive through winter on weeds and then move into nearby spring-planted mungbean crops as the nearby weeds dried out. Further research and paying close attention to any new infestations is vital to gain a better understanding of the disease

and its insect vector and develop strategies to minimise damage. We are continuing further studies to determine: the diversity of phytoplasma across crop and weed hosts and across seasons, their geographical range, which insect species are vectors, and possible management options. Monitoring surrounding weeds for phytoplasma symptoms and maintaining good farm hygiene may reduce the spread into crops.

It is currently unclear if controlling leafhoppers with an insecticide would prevent the transmission of phytoplasma. Previous experience from other insect-vectored diseases would indicate that spraying was an ineffective management technique, because transmission of the disease usually occurs early in the crop growth, and at very low vector densities – often below the level of easy detection with traditional sampling methods. Infected leafhoppers are also likely to be moving into crops from surrounding weeds (perhaps from some distance away), so spraying in-crop may have little effect to stop transmission, as they probably only need to feed for a short period to cause infection. Attempting to control the vectors through the application of multiple prophylactic sprays of a non-selective insecticide (e.g. synthetic pyrethroids, organophosphates) will also run the risk of flaring other pests like thrips, Helicoverpa, silverleaf whitefly and mites. In addition, every application of SPs and OPs selects for resistance in Helicoverpa.

Growers should monitor crops for leafhopper activity and phytoplasma infection and report any outbreaks to Qld DAF entomologists and pathologists.

Figure 1. Phytoplasma symptoms on mung bean plants often include masses of small cupped leaves (little leaf) and phyllody - when flower structures turn green and leafy and pods are either not present or are sterile. Early infected plants are often stunted. Later infected plants may have puffy pod symptoms

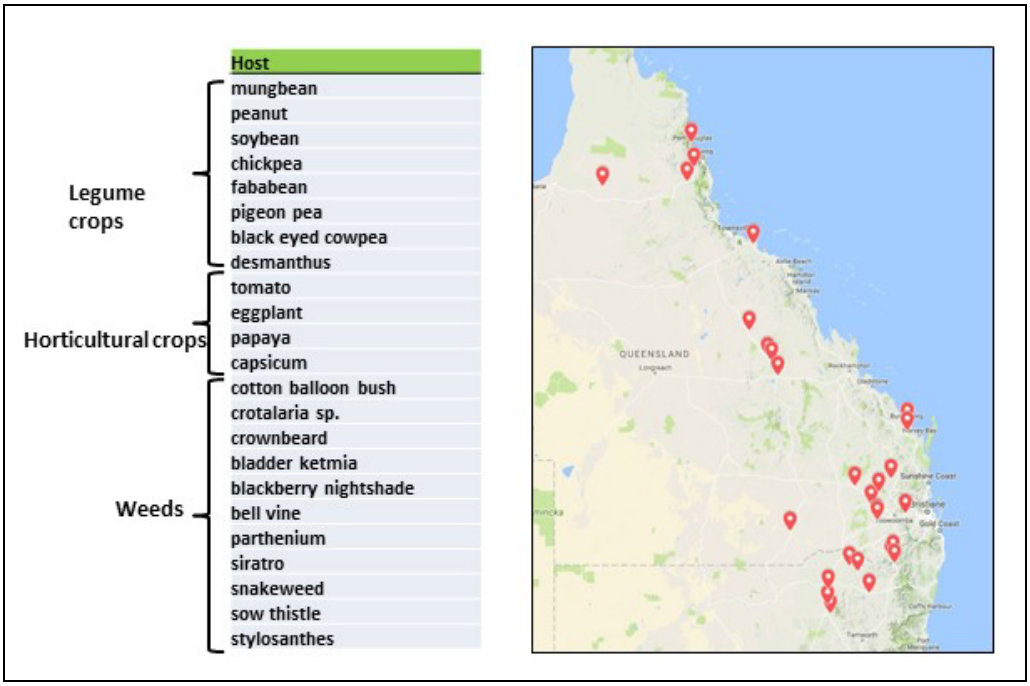

Figure 2. Map of collection sites in Northern Region for phytoplasma from crop and weed hosts. Range of hosts confirmed by molecular assay for phytoplasma

Figure 3. Soybean crop with close to 100 % incidence of phytoplasma. Symptoms included a proliferation of tiny, sterile pods; thickened and curled leaves, and prolonged greening of crop

Figure 4. Symptoms of puffy pod on mung bean include swollen, soft pods with a green mottled (net-like) appearance on exterior of pods that contain brown, deformed seeds.

Figure 5. Kernel symptoms on phytoplasma-infected peanuts (left) compared to healthy kernels (right). Symptoms were typical of peanut kernel shrivel disorder and included shrivelled away from outer shell with obviously raised, pronounced veins on kernels which may be from pinkish in colour for immature pods to dark on mature pods, and swollen funiculus on a shrivelled kernel

Figure 6. Late infected chickpea with shrivelled and marked seeds. Later flowers also display phyllody (flowers become sterile green leaf-like structures)

Figure 7. A known vector of phytoplasma, the brown leafhopper (*Orosius orientalis*) has been found in affected crops but remains unconfirmed as the vector involved in recent disease outbreaks

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC (projects DAQ00186 and DAN00202), the authors would like to thank them for their continued support.

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Residual herbicides and sowthistle - length of residual and efficacy. Trials in CQ and Darling Downs

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Key words

residual herbicides, herbicide resistance, common sowthistle

GRDC code

UQ00062

Take home messages

- Residual herbicides can offer an effective, alternative chemical approach for the fallow control of common sowthistle
- Residual herbicides provide a range of different herbicide modes of action that when used in rotation can reduce the risk for herbicide resistance
- The efficacy of residual herbicides can be different in different environments. Therefore, residual herbicides should be applied in combination with other effective weed control tactics as part of an integrated approach
- Terbyne® Xtreme® and Valor® provided the best residual control of common sowthistle as stand-alone residual herbicides and as mix partners with 'grass active' herbicides
- Herbicide mixtures provided improved control of sowthistle and are likely to provide wider spectrum control of a range of weed species
- The presence of crop residue resulted in an increased emergence of common sowthistle but did not influence the efficacy of the herbicides
- When using residual herbicides, be mindful of plant back restrictions for subsequent susceptible crop species. In dry years, residual herbicides can persist longer.

Introduction

Herbicide resistant weeds are becoming common place in farming systems throughout Australia. One such weed is common sowthistle (*Sonchus oleraceus*). In the subtropical cropping region of Queensland and northern New South Wales, herbicide resistance to fallow applied, knockdown herbicides, especially glyphosate, is making reliable control of key summer and winter fallow weeds difficult.

The first population of glyphosate resistant common sowthistle in Australia was confirmed in 2014, in a population from the Liverpool Plains, NSW (Heap, 2019). A recent (2016/17) collection of sowthistle populations from throughout Queensland and NSW is currently being evaluated for susceptibility to glyphosate. Results to date have shown that out of 154 populations tested, 26 have been confirmed resistant to glyphosate (≥20% survival) while another 17 have been identified as developing resistance (11-19% survival). The identified resistant populations are distributed throughout the northern cropping region (Figure 1). A further 59 populations are yet to be tested.

In addition to glyphosate resistance, there are sowthistle populations with resistance to chlorsulfuron (Group B). Also, poor control of sowthistle is achieved with the commonly applied fallow herbicide mixture of glyphosate + 2,4-D, due to antagonism.

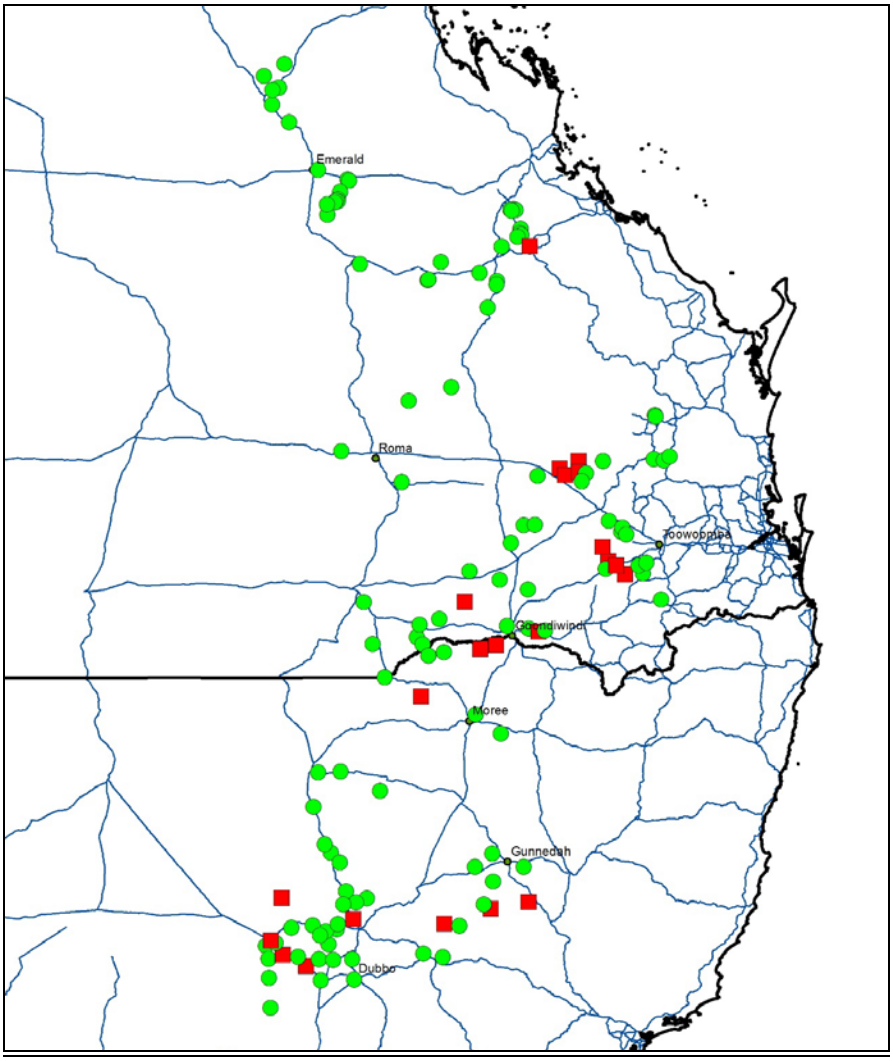

Figure 1. Map of glyphosate resistant (squares) and susceptible (dots) sowthistle (*Sonchus oleraceus*) populations across the northern grain cropping region.

Herbicide resistance in sowthistle has been caused by an over-reliance on the same herbicide and herbicide modes of action. Herbicide resistance is best managed and prevented by using a diverse range of weed management tactics in combination. Such an integrated approach may include both chemical and non-chemical weed management tactics.

Alternative tactics for sowthistle control are required. This includes examining the impact of non-chemical approaches such as targeted tillage, growing a competitive crop and cover cropping. However, there are also some potential herbicide-based options for effective fallow weed control which when used in combination with non-chemical approaches could provide effective control of sowthistle.

Residual (pre-emergent) herbicides offer an alternative to knockdown chemistries and are often able to provide longer term weed control. However, the efficacy of residual herbicides is influenced by a wide range of external and environmental factors including water run-off, volatilisation and decomposition (Figure 2). These factors will impact on the persistence and availability of residual herbicides. As such, the reliability of residual herbicides can be variable. In addition, they can persist for a long time and cause damage and yield reduction in subsequent susceptible crops.

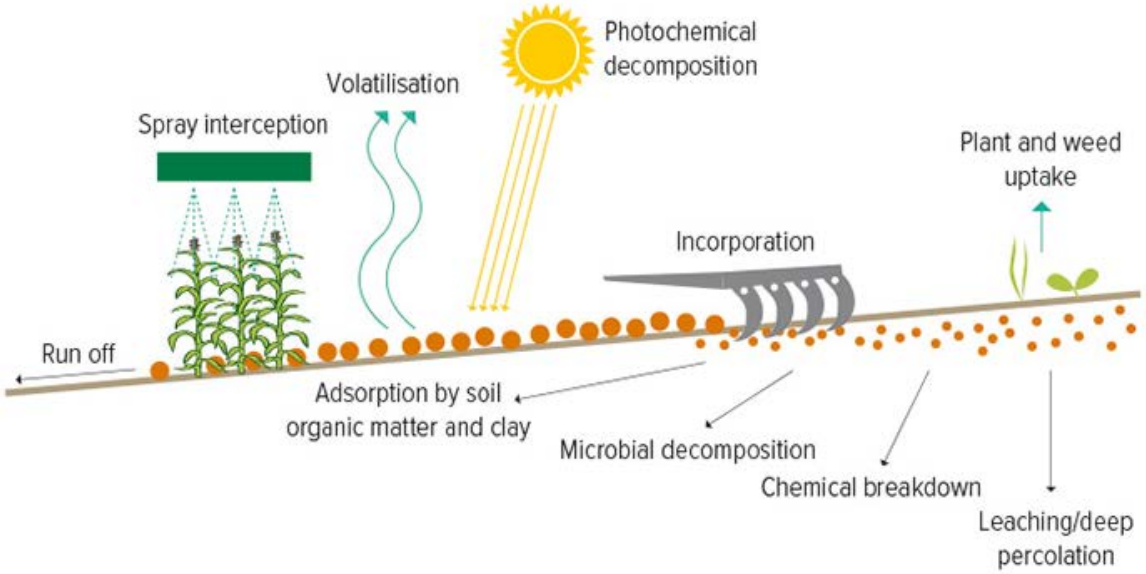

Figure 2. Factors that influence the persistence, availability and efficacy of residual herbicides *(Source: Congreve and Cameron, 2018)*

Recognising the increasing difficulty in effective fallow control of sowthistle and the potential role of residual herbicides, a series of field trials were established across Queensland to compare efficacy of residual herbicide treatments.

Materials and methods

A series of nine fallow field trials were conducted across grain growing regions of Queensland (south-west Queensland, Darling Downs and central Queensland) (Table 1) during summer/autumn 2016/17 to evaluate the efficacy and persistence of a range of residual herbicides for the control of sowthistle in fallow. Sites were selected that had a recent history of sowthistle infestation. Unfortunately, one site (Callandoon) did not have any sowthistle emerge, and two sites (Mt McLaren and Gindie 1) had populations too low to measure significant differences. The site at Jondaryan (1) also had additional treatments of crop residue retained and removed.

Residual herbicides were applied to small plots (ranging in size from 3 x 12m^2 to 6 x 20m^2) along with two unsprayed controls (Table 2). The herbicides were evaluated in combination with grass weed residual herbicides, as fallow grass weeds were also a target. Herbicides were applied using a quad-bike at 100L/ha of water with an air-inducted course (C) droplet size. Sowthistle emergence counts were made after each flush of emergence, following sufficient rain, and any emerged weeds were sprayed out with a knockdown herbicide so as to avoid double counting.

Table 1. Location of trial sites and other details.

Site location	Soil type	Treatments applied	Sowthistle (yes/no)
South-west Queensland			
Callandoon	Alluvial box flat	27 October 2016	No
Yagaburne	Brigalow	20 April 2017	Yes
Mungindi	Coolibah	3 March 2017	Yes
Darling Downs			
Jondaryan (1)	Black Vertosol	9 November 2016	Yes
Jondaryan (2)	Black Vertosol	27 April 2017	Yes
Jandowae	Grey Vertosol	23 November 2016	Yes
Central Queensland			
Mount McLaren	Open downs	3 May 2017	Low
Gindie (1)	Open downs	5 April 2017	Low
Gindie	Brigalow	27 April 2017	Yes

Table 2. Residual herbicide treatments applied at 6 Queensland sites for the control of common sowthistle. Please note: Not all products tested are registered for use in fallow or pre-sowing. Products not registered for use in fallow or pre-sowing have been expressed by their mode of action (MOA) group only. Please check labels for use patterns and only apply as per label.

Trt no	**Product/s**	**Grams active ingredient (g.a.i.)/L or kg**	**MOA**	**Rate (/ha)**	**Registered control of Grass (G), Broadleaf (B), Sowthistle (ST)**	**Number of sites** (out of 5 or 6 field trials) with significant reduction in sow thistle emergence.	**Indicative price ($/ha)**
1	Untreated control		-				
2	Flame® (imazapic)	240	B	200 mL	G, B	1/6	4
3	Terbyne® Xtreme® (terbuthylazine)	875	C	1.2 kg	B, ST	4/6	35
4	Group C triazine	900	C	3.3 kg	G, B, ST	1/6	26
5	Stomp® Xtra* (pendimethalin)	455	D	3.3 L	G, B, ST	0/6	53
6	Balance® (isoxaflutole)	750	H	100 g	G, B, ST	2/6	16
7	Dual® Gold (S-metolachlor)	960	K	2 L	G, B, ST	0/6	26
8	Valor® (flumioxazin)	500	G	280 g	G, B, ST	4/6	53
9	Flame® (imazapic) + Balance (isoxaflutole)	240 + 750	B + H	200 mL + 100 g		4/6	20
10	Terbyne® Xtreme® (Terbuthylazine + Flame® (Imazapic)	875 + 240	B + C	1.2 kg + 200 mL		5/6	39
11	Terbyne® Xtreme® (terbuthylazine + Stomp Xtra* (pendimethalin)	875 + 455	C + D	1.2 kg + 3.3 L		5/6	88
12	Group C (triazine) + Dual® Gold (S-metolachlor)	900 + 960	C + K	2 kg + 2 L		2/5	42
13	Valor® (flumioxazin) + Flame® (imazapic)	500 + 240	G + B	280 g + 200 mL		4/6	57
14	Stomp Xtra* (pendimethalin) + Balance (isoxaflutole)	455 + 750	D + H	3.3 L + 100 g		3/6	70
15	Flame® (imazapic) + Stomp Xtra* (pendimethalin)	240 + 455	B + D	200 mL + 3.3 L		3/6	57
16	Balance (isoxaflutole) + Dual® Gold (S-metolachlor)	750 + 960	H + K	100 g + 2 L		1/6	42
17	Terbyne® Xtreme® (terbuthylazine + Balance (isoxaflutole)	875 + 750	C + H	1.2 kg + 100 g		4/6	50
18	Flame® (imazapic) + Dual® Gold (S-metolachlor)	240 + 960	B + K	200 mL + 2L		3/6	30
19	Valor® (Flumioxazin) + Dual® Gold (S-metolachlor)	500 + 960	G + K	280 g + 2 L		5/6	80

*Stomp Xtra no longer registered, but other products with pendimethalin are available

Results

The efficacy of the residual herbicide treatments was not consistent across sites. However, there were some treatments that provided more consistent, effective suppression of sowthistle emergence (Table 2). Terbyne Xtreme (terbuthylazine) and Valor (flumioxazin) applied alone provided effective control of sowthistle at four out of six trial sites. Mixtures with these two herbicides, also provided good control when Terbyne Xtreme (terbuthylazine) was mixed with Flame (imazapic) (5/6), Balance (isoxaflutole) (4/6) or Stomp Xtra* (pendimethalin) (5/6) and when Valor (flumioxazin) was mixed with Flame (imazapic) (4/6) or Dual® Gold (s-metolachlor) (5/6). Good control was also achieved from a mixture of Flame (imazapic) with Balance (isoxaflutole) (4/6) and with Flame (imazapic) + either Stomp Xtra* (pendimethalin) or Dual® Gold (s-metolachlor) (3/6).

The duration of control differed for the different residual herbicide treatments. For example, at the Yagaburne site, all residual treatments initially provided a significant reduction in sowthistle emergence at 40 days after application (DAA). However, at 187 DAA, efficacy was greatly reduced in all but six of the treatments (Figure 3). The duration of persistence will impact on the efficacy of weed control but can also impact on the potential damage to subsequent susceptible crops. Dry years, such as we have had recently, will generally increase the persistence of many residual herbicides beyond the time frames stated on labels.

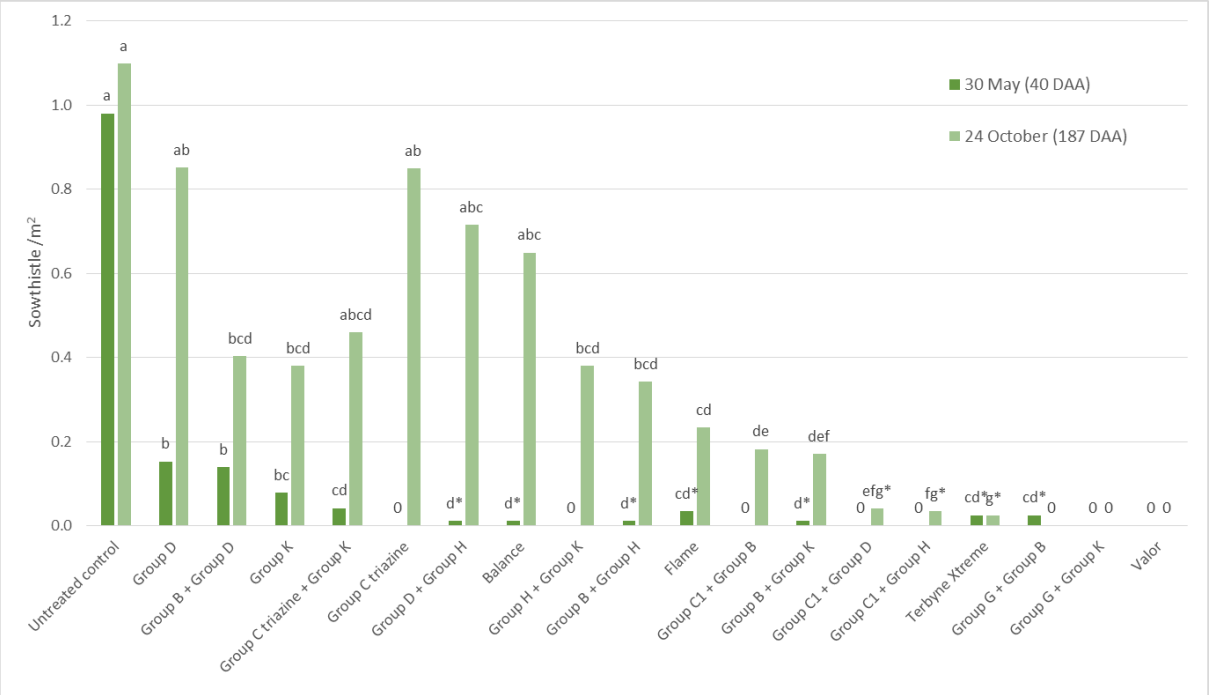

Figure 3. Sowthistle emergence (plants/m^2) at Yagaburne following application of residual herbicides and counted 40 Days after application (DAA) (30 May 2017) and 187 DAA (24 October 2017). Columns within the same assessment with similar letters are not significantly different
* = not significantly different to 0. (P=0.05).

Retaining crop stubble resulted in an increase in the emergence of sowthistle (Figure 4). Sowthistle requires an extended period (three days) of moisture to germinate and it is likely moisture was retained for longer under the crop stubble than in a bare fallow. Stubble did not have any influence on the efficacy of the residual herbicides, with the same trend in control being achieved with or without crop stubble (Figure 4). However, previous research has shown crop residues can intercept large proportions of residual herbicides, stopping them from getting to the soil target.

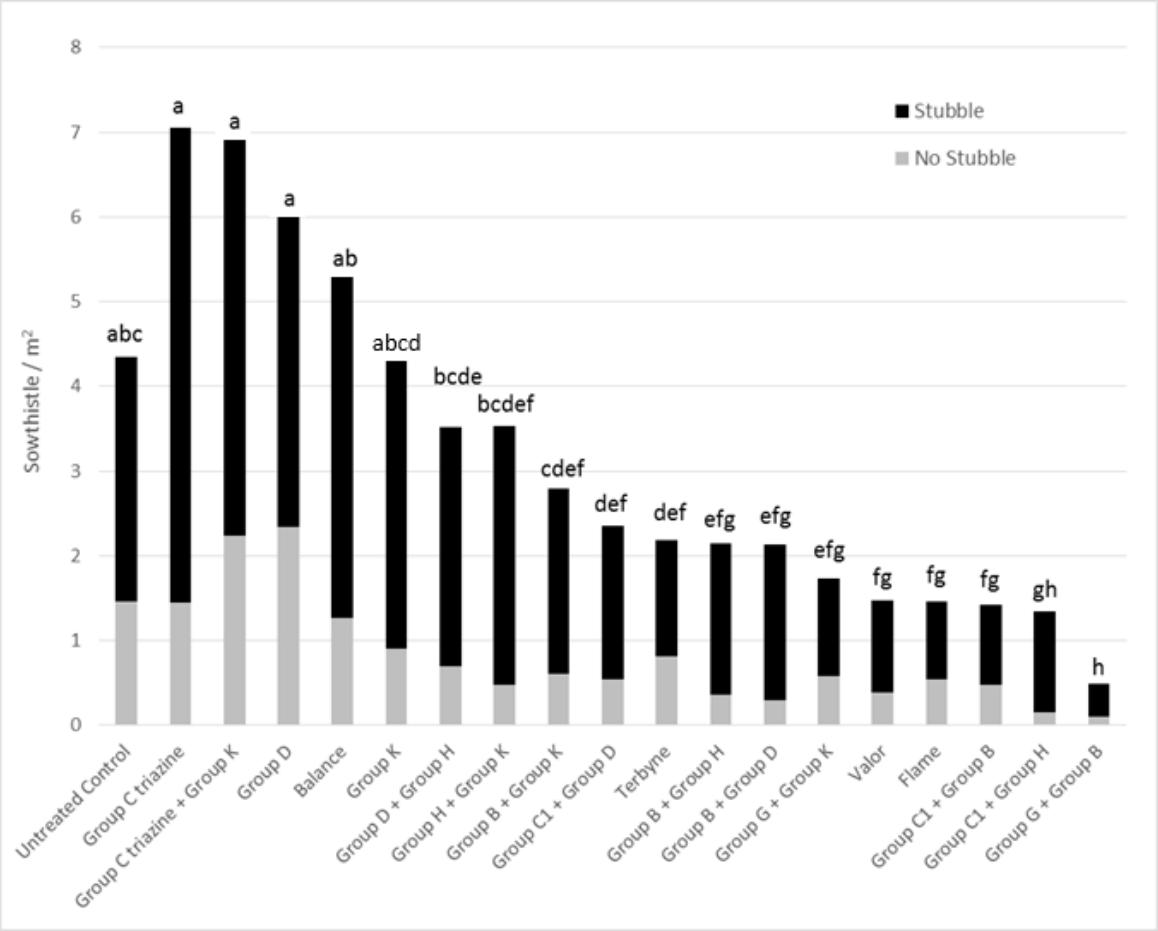

Figure 4. Sowthistle emergence (plants/m^2) at Jondaryan (1) following application of residual herbicides in plots with crop stubble and without crop stubble. Counts were made 147 DAA (5 April 2017). Columns with similar letters are not significantly different (P=0.05)

Conclusion

Rotating weed control tactics is a key strategy in the management and prevention of herbicide resistance. Weed management shouldn't be prescriptive but should consider the environment (soil type, likely rainfall etc.) and future cropping aspirations. As such the results presented in this paper are to help inform decision making and are not a recommendation for weed control.

Our results show there are residual herbicide options for the effective suppression of sowthistle emergence in fallows. Residual herbicides offer an opportunity for prolonged control of multiple flushes of sowthistle emergence and for mode of action rotation. Applying residual herbicides in mixture, while more costly, is likely to provide better control of a broader spectrum of weeds.

As residual herbicides can be variable in their efficacy, it is important to use residual herbicides in combination with other weed management tactics. For example, if applying a residual for fallow weed control, make sure any weed escapes are controlled, either with knockdown herbicides, targeted tillage or manual removal. Consider planting a subsequent competitive crop to provide added control.

Many herbicides require moisture to break down. With our recent run of hot, dry seasons, be mindful that some residual herbicides can persist for longer than described on their labels. A test plot of your planned subsequent crop can give you a good idea of whether crop damage is likely to

occur. Current research is looking at developing a quick test for testing soils to determine concentration of the herbicide and risk of damage for subsequent susceptible crops.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

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Deep P update 2019 – Multi-year grain yield impacts and economic returns for southern Queensland cropping

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Key words

phosphorus, starter P, deep P, residual value, placement strategies

GRDC code

UQ00063

Take home messages

- You know your paddock variability for yield – use that to prepare a soil sampling program
- Look at the fertility and constraint status of the soil profiles
- For southern Queensland, placing phosphorus at depth has produced statistically significant yield responses in 26 out of 35 crop seasons. The cropping program has been dominated by winter crops at these sites (27 of 35 crop-seasons), with wheat and barley responding positively in all 15 site-years and chickpea in 6 out of 12 crop seasons. Sorghum has responded in 4 out of the 6 site-years. Whether these differences in response frequency relate to seasonal moisture availability, soil P status or inherent differences in the ability of crops to utilise deep P bands is being explored in other projects and additional experiments
- Effects of deep placed P on grain P concentration were small, so grain P removal (export) is primarily driven by crop yield
- It is still challenging to estimate what re-application timeframes for deep P re-application look like, given other nutrient limits and varying seasonal conditions, plus the lack of a method to directly account for fertiliser P recovery and export.

The trial program and experimental design

Field research as part of UQ00063 commenced in the winter of 2012. Since then a total of 12 sites across the eastern Downs (2), western Downs (8) and Maranoa (2) have been established. Experiments have generally consisted of rates of Phosphorus (P) applied in bands at ~20cm depth on spacings of 50cm, along with an untilled farmer reference treatment. Application rates at depth, range from 0 to 60 or 80 kg P/ha. Table 1 displays the structure of deep treatments used in the two experiments established in the Maranoa. Initial experiments in 2012 (4 sites) used triple superphosphate (TSP) as the P source for deep treatments while subsequent sites used monoammonium phosphate (MAP). Due to poor efficacy at higher soil pH values, the TSP sites where not continued from 2016. Effects on yield are reported separating the TSP and MAP site responses.

A basal nutrient application of nitrogen, sulfur and zinc was added to the deep application to balance the rates of N added as MAP and lower the risk of other nutrient limitations constraining P responses. Potassium was also applied at one location. A location on the eastern Downs that subsequently proved to be potassium limited is not reported as part of this summary. Full agronomic details for experiments are contained in Gentry and Grundy (2018).

All main plots were split to annual 'with' and 'without' starter P fertiliser applications at planting, to test for any interactions between starter P (standard practice) and deep P applications (i.e. were effects independent or could one application method substitute for the other). The choice of starter

product and rate represented grower practice at each site. The crop sequence at each site was dependant on the local rotation, and the residual benefit of the different rates of deep P was tracked through subsequent growing seasons.

Table 1. Experimental treatments for Mt Bindango deep placed P sites (FR=Untilled Farmer Reference treatment– no P fertiliser applied)

Deep P treatment nutrient application rates (kg/ha)							
Treatment no	1	2	3	4	5	6	7
P rate (as Mono Ammonium Phosphate)	FR	0	10	20	30	40	60
N rate (from MAP and Urea)	-	40	40	40	40	40	40
Zn rate (Zinc Chelate)	-	2.0	2.0	2.0	2.0	2.0	2.0

Measurements of crop response typically comprised biomass cuts at physiological maturity, to determine crop growth response and nutrient acquisition, in addition to machine harvested grain yields. Grain was also analysed for nutrient composition to calculate nutrient export.

Yield effects of starter and deep P were determined using ANOVA (VSN International 2017).

A subsequent analysis investigated the potential impact of the deep tillage and basal nutrient (as a surrogate for ripping effect) using REML (VSN International 2017) comparing just the FR (untreated) and 0P treatments, with/without starter application. This approach considers all the yield data for the site year, but just focuses on those two treatments, and their potential interaction.

Effects of starter P, deep P and starter P x seep P interactions

Results are based on analysis of each crop as an individual year, with a table summarising the response frequency for the different winter or summer species (Table 2). “Winter cereals” combines mainly wheat crops with only 2 barley crops grown. Individual site analyses are shown in the appendix Table 1. The number of experiment-years for each crop varies as two locations did not have starter applied. Statistical significance for the starter treatment needs to be interpreted conservatively as the experimental design was only testing presence or absence of the fertiliser and so has limited the experimental ability to determine influence. It should be noted that while starter P responses are based on fresh applications in each crop season, deep P effects represent the average response across sites that have had up to five crop seasons after the application of deep P and the other basal nutrients.

Table 2. Summary of statistical significances ($p <= 0.05$) for southern Queensland sites to starter, deep or interactions for fertiliser P

	Starter responses	Deep	Starter x deep
Winter Cereals	11 of 14 crops	15 of 15 crops	3 of 15 crops
Chickpeas	2 of 11 crops	6 of 12 crops	2 of 11 crops
Sorghum	0 of 6 crops	4 of 6 crops	0 of 6 crops
Mungbean	1 of 2 crops	1 of 2 crops	0 of 2 crops

Summary of results

Winter cereals – wheat and barley

Winter cereals consistently responded to having both starter fertiliser applied at sowing and to application of deep P, with very few crops showing an interaction between starter and deep P. From the 3 sites where statistically significant interactions were recorded, only 1 result appeared to be a

genuine interaction, with the others a product of unexplained data variability. These results then reduce fertiliser P management into two independent decisions for winter cereals in southern Queensland: one about starter fertiliser use, and the other for deep placement. Yield gain when starter P was applied averaged 210 kg/ha (7.6%) across all sites for wheat and barley, compared to no starter fertiliser.

Assuming P costs of $3.60/kg and typical starter-P rates of 6-12 kg/ha, applications represent a cost of approximately $20 - $40/ha. This cost is easily returned by the $84/ha from an average 210kg yield gain. At current prices, the response to starter provides a positive economic return to growers and so should be considered as a part of normal recommended practice. Grain prices would have to fall to below $200/t before this yield benefit would not add extra profit from 12kg of P, and below $100/t for 6kg/ha of starter P to not be profitable.

Deep P at 20 kg P/ha applied as either TSP or MAP has increased average grain yield at winter cereal sites by 9-13% (Table 3). Comparisons between TSP and MAP sites using cross-site statistical techniques, and in-field comparisons of P fertiliser choice are underway currently in UQ00078 to explore further the product choice options. With the MAP sites, increasing the deep P rate to 30 kg P/ha generated mean increases of 380 kg/ha (range 141-826) resulting in an additional 15% yield increase.

Table 3. Winter cereal yield change summary for deep placed TSP or MAP at 20 kg P/ha (FR=Untilled Farmer Reference – no P fertiliser applied)

Deep P source	Number of crop-years	FR yield (kg/ha)	Average yield change with 20 kg P/ha deep	Range of responses with 20 kg P/ha deep
TSP	5	2426	+217 (9%)	+115-341
MAP	10	2522	+325 (13%)	+117-707

Chickpeas

Like the situation with winter cereals, chickpeas exhibited a low frequency of starter x deep P interactions, and again the two sites where these were significant were likely artefacts resulting from unexplained data variability. As outlined in Bell *et al.* (2016), chickpeas do not have an obligate requirement for starter application to set grain number (unlike cereal grain crops) and the very small number of responses to starter application (2 of 11 crops) is consistent with this (Table 2). However, there are situations where chickpeas were deep-sown into subsoils with very low available P, so the probability of starter P responses in these situations is greater.

The average chickpea yield without starter across all sites was 1747 kg/ha, compared to 1822 kg/ha with starter – a 75 kg/ha difference. Where that comparison was restricted to the two significant 'starter-responsive' sites, the yield increase from starter application averaged 300 kg/ha (1710 kg/ha without starter, 2010 kg/ha with).

At $800/t, even the overall average of 75 kg/ha increase in chickpea yield easily covers the cost of $20-40/ha of starter P, and the observed upper end responses would generate over $200 in additional profit for growers. To improve the reliability of starter P responses, growers should consider further on-farm experimentation – especially comparing responsiveness under deep sowing or normal sowing conditions.

It has been more difficult to make conclusive interpretations of deep P effects in chickpea crops in southern Queensland, with only half of the crops (6 from 12) showing statistically significant responses to deep P (Table 2).

Table 4. Chickpea yield change summary for deep placed TSP or MAP at 20 kg P/ha (FR=Untilled Farmer Reference – no P fertiliser applied)

Deep P source	Number of crop-years	FR yield (kg/ha)	Average yield change with 20 kg P/ha deep	Range of responses with 20 kg P/ha deep
TSP	7	2007	+56 (3%)	-172 to +249
MAP	5	1203	+133 (11%)	-144 to 535

The reasons for this more variable response are unclear, particularly in the light of the more consistent responses recorded in central Queensland. Dry matter responses to deep P were larger and more consistent than grain responses with an average increase of 500 kg/ha (10%). As harvest index for pulse crops is not relatively constant (compared to grass crops), this suggests that growth responses to P are not necessarily translating into yield responses. Further investigation into the relationship between P supply, biomass growth and establishment of grain yield in chickpea would appear to be needed to explain these interactions.

Sorghum

None of the sorghum crops grown in the current study period (2013-14 to 2017-18) recorded any statistical effect of starter application. Average grain yields without/with starter application also indicate a negligible effect (3404 kg/ha without vs 3376 kg/ha with). Warm soil conditions allowing rapid root expansion, combined with high potential evaporative loss in surface layers, may allow rapid early exploitation of P in the top soil layers but then limit the duration of access to the starter P band.

Deep P as MAP at 20 kg P/ha increased average grain yield from 3431 kg/ha in untreated plots by 311 kg/ha (Table 5). Application of 30 kg P/ha increased average yields slightly more with an average 372 kg/gain (11%, 319 – 514 kg/ha range). With only two crops on the TSP sites it is difficult to make much assessment on performance.

Table 5. Sorghum yield change summary for deep placed TSP or MAP at 20 kg P/ha (FR=Untilled Farmer Reference – no P fertiliser applied)

Deep P source	Number of crop-years	FR yield (kg/ha)	Average yield change with 20 kg P/ha deep	Range of responses with 20 kg P/ha deep
TSP	2	2924	69 (2%)	54 - 84
MAP	4	3431	311 (9%)	-44 – 517

Mungbean

The very limited set of mungbean data makes robust recommendations challenging. Like sorghum and chickpea, starter application showed negligible effects on mean yield (876 kg/ha without starter vs 908 kg/ha with starter). Similarly, deep P has provided only small average yield increases of 67 kg/ha for mean untreated yields of 837 kg/ha.

Economic assessment of deep P

As Deep-P involves large upfront costs (~$100/ha for 20kg P) it is important to identify how many crops it takes for this investment to be repaid, and how long this investment will continue to generate additional income. Of the 11 sites for deep P experiments in southern Queensland, 8 had

repaid the investment in 20 kg/ha P and returned increased profit within 2 years and 5 of those had managed to do so in the first year. The 20 kg/ha P treatment at Jimbour West, which has had 5 crops between winter 2014 and winter 2018, has returned almost $800/ha in increased profit over this time period.

Potential tillage impacts on response with deep P

As outlined earlier, a contrast analysis just comparing the factorial effects of +/- starter and +/- deep rip plus basal nutrients was conducted. This approach focusses on these treatments inside the broader yield data for the site and crop in that year.

Results of this analysis indicate there was no substantial impact of deep tillage and basal application on their own, relative to current grower practice, with only 2 of the 35 crop seasons showing any statistically significant response.

Grain P concentrations with deep P treatment

Across the southern Queensland trial program, there were contrasting effects on grain P concentration between the grass and pulse species. For wheat and barley, 20 kg P/ha at depth increased grain P concentrations by an average of 150 mg P/kg (or 0.15 kg P/t). Grain P concentration in FR plots averaged 2260 mg P/kg (2.26 kg P/t) and with the 20 kg deep P/ha it increased to 2410 mg P/kg (2.41 kg P/t). At average grain yield for 20 kg P/ha applied deep, only an additional 1.1 kg P/ha leaves the paddock compared to the treatment without deep P.

Chickpea grain P concentrations showed greater responses to deep P applications, with 20 kg deep P/ha increasing grain P concentration by 330 mg P/kg (0.33 kg P/t). However, grain yield increases were smaller, so the change in P removed from the field with a 20 kg P/ha treatment was an increase of 1.2 kg P/ha, comparable to that of winter cereals.

The small differences in P removal rates with deep P application suggest that it will be difficult to use "cheque book" accounting to monitor depletion of deep placed P treatments. These data also suggest that while P applications can generate significant yield responses and improved profitability, they are also not having a large impact on crop P status. Grain P concentrations <2500-2900 mg P/kg are purported to indicate suboptimal crop P status in wheat, but even with a combination of deep P and starter P applications, average grain P concentrations still average only 2400 mg P/kg. These data therefore highlight the fact that once profile P becomes severely depleted, restoring soil P status with fertilizer applications will be a slow process that requires careful ongoing management.

Average additional P removal of ≈ 1.0-1.2 kg P/ha would appear to suggest an extended lifespan from a deep P application of 20 kg P/ha. However, it is unknown how residual fertiliser P availability will be impacted over time by chemical reactions that occur in the fertiliser band, and how those reactions might vary between soil types. Additional work to explore the chemistry of residual P availability is currently being conducted by a GRDC-funded postdoctoral fellow at University of Queensland.

Suggested on-farm research treatments

This field research was conducted under carefully managed experimental conditions. Before commencing a large-scale nutrient application program, growers are urged to appropriately soil test their fields to establish available nutrient concentrations in the surface and subsurface layers, and to identify the potential constraints to yield. They are then encouraged to evaluate the crop responses to fertiliser applications designed to address those yield constraints using an appropriate program of strip-trials and on-farm exploration to validate the diagnosis of nutrient constraints.

There are four suggested treatments to explore the effects of a deep P application before starting a larger program (Table 6):

1. Treatment 1 is current practice or “do nothing”, which benchmarks current system performance;
2. Treatment 2 involves the physical tillage of soil to a depth or roughly 20-25 cm, which simulates the deep placement operation without any fertiliser application. While not a long-term solution, simply loosening soils can sometimes allow better root exploration of those profile layers and allow more efficient uptake of scarce soil P resources.
3. Treatment 3 is tillage with additional nitrogen. In many sites, nitrogen status is in equilibrium with the existing ‘normal’ yields from that field, and if deep P improves field yield potential, extra N has to be applied to achieve the higher yield target. Applying additional N alone in this treatment allows growers to separate responses from tillage, extra N, and extra N and P.
4. The last treatment is deep P application. Given that MAP is the most effective form of P, and soil Zn is often also low, an application of 100-150 kg/ha of an ammonium phosphate product with Zinc is typically used. Suggested rates for use in strip trials are 20-30 kg P/ha of an ammonium phosphate-based product. Placement of the P needs to be such that crops are going to be likely to access it. Plant roots must have a high probability of encountering the applied P early in the growth stage, so band spacings of 50 cm or less are suggested to maximise the chances of roots from each crop row encountering some of the applied nutrients.

Table 6. Suggested on-farm deep P treatments

Treatment	Rip (≈ 20-25 cm)	Deep N (≈ 30/50 kg N/ha)	Deep N+P+Zn (30/50 kg N/ha + 20/30 kg P/ha + Zn/ha)
1			
2	Y		
3	Y	Y	
4	Y	Y	Y

Treatments should be done in a way to make recording of yield response simple. The easiest strategies involve full-length field strips (ideally two or three header widths together) and also replicated several times within and across fields. Talking with precision ag practitioners, the minimum treated area to produce reliable yield estimates with harvester yield monitors is 1 ha in 5-6 header widths.

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The research undertaken as part of project UQ00063 was made possible by the significant contributions of growers who host the field trials and the financial support of the GRDC. The authors would like to acknowledge these contributions and thank both groups for their continued support.

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Supplementary Table 1. Individual site by statistical significance for starter, deep or interaction

Crop	Starter	Deep P	Starter * Deep P
Westmar - ANOVA			
2014 Wheat	*	***	n.s.
2015 Chickpea	n.s.	n.s.	n.s.
2016 Chickpea	n.s.	**	n.s.
Inglestone - ANOVA			
2013 Wheat	*	***	***
2014 Chickpea	**	**	n.s.
2015 Chickpea	n.s.	***	***
Lundavra #1 - ANOVA			
2013 Wheat	No Starter	*	No Starter
2014 Chickpea	n.s.	*	*
2015 Wheat	n.s.	***	n.s.
2016-17 Sorghum	n.s.	n.s.	n.s.
Lundavra #2 - ANOVA			
2013 Chickpea	No Starter	n.s.	No Starter
2014 Wheat	n.s.	*	*
2015-16 Sorghum	n.s.	***	n.s.
2016 Chickpea	n.s.	n.s.	n.s.
Wondalli - ANOVA			
2013-14 Sorghum	n.s.	***	n.s.
2015 Wheat	***	***	n.s.
2017 Wheat	***	*	n.s.
Condamine #1 - ANOVA			
2015-16 Sorghum	n.s.	n.s.	n.s.
2017-18 Mungbean	n.s.	n.s.	n.s.
Condamine #2 - ANOVA			
Crop	Starter	Deep P	Starter * Deep P
2014 Chickpea	n.s.	n.s.	n.s.
2015 Wheat	*	*	***
2017 Wheat	**	**	n.s.
2018 Wheat	**	***	n.s.
Mount Carmel - ANOVA			
2013-14 Sorghum	n.s.	**	n.s.
Jimbour West #1 - ANOVA			
2014 Barley	*	***	n.s.
2014-15 Mungbean	*	**	n.s.
2015-16 Sorghum	n.s.	*	n.s.
2017 Chickpea	*	***	n.s.
2018 Barley	**	***	n.s.
Mt Bindango #1 – ANOVA			
2016 Wheat	*	***	n.s.
2017 Wheat	*	**	n.s.
2018 Chickpea	n.s.	*	n.s.
Mt Bindango #2 – ANOVA			
2016 Chickpea	n.s.	n.s.	n.s.
2017 Wheat	n.s.	*	n.s.
2018 Chickpea	n.s.	n.s.	n.s.
n.s. = not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$			

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Deep applied phosphorus at "Culara" Condamine

Ben Taylor, "Culara"

Key words

phosphorus, starter P, deep P, grower

Take home messages

- Before considering deep P, the whole farm system needs to be considered.
- You can't expect to see full potential of P (or any input) if the whole system isn't in order to gain maximum potential when the opportunity is given.

Demographics

Location of farm: "Culara" Condamine
Hectares: 4000
Key enterprises: 5 year rotation of: wheat, chickpea, wheat, long fallow, sorghum/cotton

Overview of "Culara"

- Family operation of owned and leased land located south of Condamine consisting of Brigalow/Belah and Wilga tree country.
- Equipment used are Case Rowtrack 400 and 12m Excel Stubble Warrior with CR600 parallelogram units on 375mm spacing.
- Applying 100-120kg of MAP over 500 – 800ha per year for the last 5 years.

Why? - Our observations

- Sorghum configuration/fertilizer trial
- Deep spray tracks after laser levelling
- Articles in GRDC magazine, practical observations and MCA led us to the decision of giving deep applied phosphorus a go

Costs

- MAP @ $740 on farm applied @ 120kg of MAP = $89/ha cost
- Fuel cost using 70l/hr of fuel covering roughly 10ha/hr = $7/ha
- Machine Cost = $20/ha
- Total cost per ha = $116/ha

Yield benefits

- Yield advantages of 600kg to 1200kg/ha.
    - 900kg of wheat @ $300/t = $270/ha extra income minus $116/ha cost = $154 increase of income/ha
- Header data only. Not accurate weigh bin data.
- Long fallow/rotations.

- 5 year plan - however some research suggest benefits of application could last longer than that.

Conclusion

Before considering deep P, the whole farm system needs to be considered.

1. Is good weed control in place?
2. Is nitrogen and other nutrition in order?
3. Is the profile of moisture managed to give crops full yield potential?
4. What equipment do I need to look at modifying/investing in?
5. Apply in good conditions to be lees aggressive on the equipment.

You can't expect to see full potential of P (or any input) if the whole system isn't in order to gain maximum potential when the opportunity is given.

Figure 1. Deep applying MAP in Sorghum stubble after rain to a depth of 18cm.

Figure 2. Millet cover crop planted after deep applying MAP (Deep P on left, untreated on right).

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