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Contents

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Yield gaps - how much yield potential is left behind by better growers on the Central West and why? Identifying areas to capture lost yield and profit

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Key words

Yield gap, wheat, management, biophysical factors, farm attributes, farmer attributes

GRDC code

CSA00055

Take home messages

- Average wheat yields between 2000 and 2014 for the central west (1.4 t/ha) are 2.2 t/ha below the water-limited yield potential (Yw) for dryland wheat. On average, this is costing growers $550/ha
- A national survey of 232 growers found a median yield gap of 36% for wheat grown in 2016. There was a 49% difference between average yield gaps of the top half compared with the bottom half of those surveyed.
- The national average N fertiliser rate of 45 kg N/ha restricts yield to 60% of Yw. For Nyngan this rate restricts yield to 88% of Yw and for Condobolin to 72%. Failure to control weeds during the summer fallow could restrict yield to 74% of Yw nationally, 60% of Yw in Nyngan and 84% in Condobolin. A two week delay in sowing wheat restricts yields nationally to 93% of Yw, 92% of Yw in Nyngan and 82% in Condobolin.
- An emerging practice of sowing early (before 26 April) with a late maturing variety and flexible N fertiliser application is expected to have the potential to increase the yield frontier by 30% where this can be implemented.
- This emerging best practice has the potential to increase financial returns in the central west from about $760/ha to about $1,650/ha. This emerging practice has been proven in many sites south of Dubbo and should be further investigated in local fields by growers, consultants and researchers.

Introduction

It is well known that Australia's growers are among the best in the world. So why is the yield gap in the central west subregion 61% of the yield potential? Between 2000 and 2014 average annual wheat yield (Ya) was 1.4 t/ha while the water–limited yield potential (Yw) was 3.5 t/ha. This means that there is a potential yield gap of 2.2 t/ha or $550 per ha (@250 $/t) that is not being realised (www.yieldgapaustralia.com.au).

We ask why such a substantial yield gap exists and why some growers achieve their yield potential while others do not. We examined this in three different ways:

1. A grower survey that investigated how farms with large yield gaps differ from farms with low yield gaps by relating yield gaps to grower characteristics, farm characteristics and farm management practices.
2. A simulation study that examined the impact of sub-optimal management practices at 50 weather stations spanning the Australian grain zone.
3. An economic (risk-adjusted profit) analysis that explored the results from the simulation study.

Grower survey

The survey aimed to comprehensively examine farm management practices as well as farm and farmer characteristics that may contribute to the wheat yield gaps in Australia. Using the GRDC customer relation database we conducted telephone interviews of 232 wheat producers from 14 contrasting local areas (SA2s; roughly equivalent to a shire) in the Australian grain zone (Figure 1).

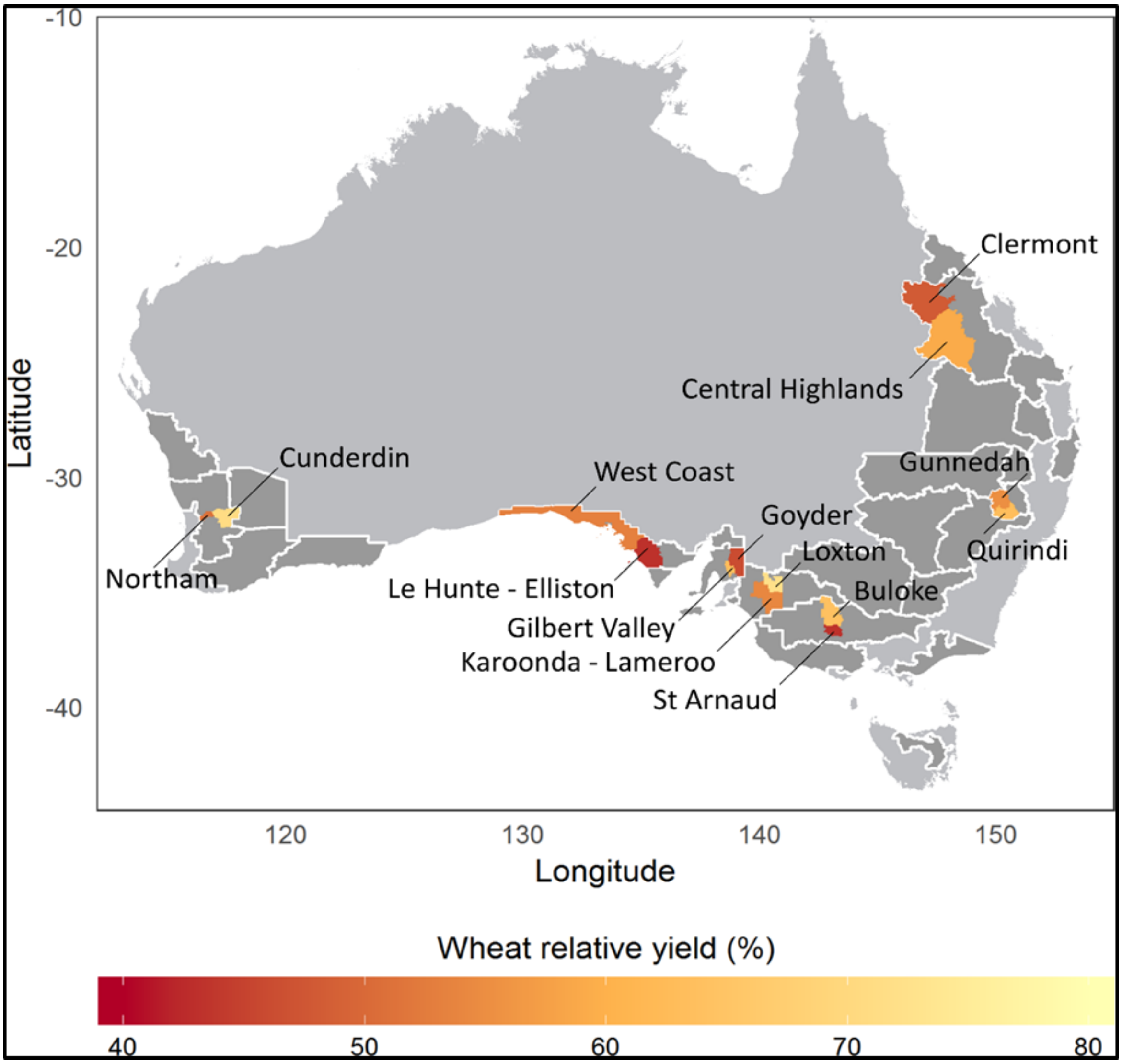

Figure 1. Locations of surveyed local statistical areas (SA2s) with contrasting average relative yields. The relative yield of wheat (% of water-limited yield potential) is indicated by the red-yellow colour gradient. The white borders shows the GRDC sub-regions of the Australian grain zone

The average participants' age was 51 years old (SD = 11, ranging from 20 to 89 years in age), with an average of 31 years (SD = 13) of experience in growing crops. Among the participants, there were only 10 female producers (4%). Seventeen participants (7%) identified as corporate farms while the rest identified as family farms. Thirty three participants (14%) owned or managed other farms in locations more than 50 km apart. The average cropping land area was 2,149 hectares (SD = 2,073). The total area cropped by participants was 0.5 million hectares, or about 2% of Australia's cropped area.

Each farm's yield gap was calculated by comparing their reported wheat yield in 2016 against the calculated water-limited yield potential, simulated under best management practices for their three dominant soil types, using weather data from all stations in their postcode. All farms were ranked according to their relative yields (Y% = 100 X Ya/Yw). The median relative yield was 64% and this value was used as a cut-off for dividing the respondents into two equal sized groups: the high relative yield (=small yield gap) group (mean Y% = 96%; SD = 20%) and the low relative yield (= large yield gap) group (mean Y% = 47%; SD = 12%). Hence, an average yield gap of 49% exists between these two groups. All survey responses were analysed to determine if there were significant differences in how the high and low relative yield groups responded.

The results revealed significant differences between farms with smaller yield gaps and those with greater yield gaps in relation to farming management, farm characteristics, and grower characteristics. Australian farms with smaller yield gaps (high relative yield) are more likely to be smaller holdings (high relative yield: Mean = 1886 ha, SD = 1993 vs low relative yield: Mean = 2395 ha, SD = 2127; p = .061), growing less wheat (high relative yield: Mean = 743 ha, SD = 880 vs low relative yield: M = 1171 ha, SD = 1111.2; p = .001) on more favourable soil types. These growers are more likely to apply considerably more N fertiliser to their wheat crop (Table 1), to grow a greater variety of crops, to soil-test a greater proportion of their fields, to have less area affected by herbicide-resistant weeds, and to be early adopters of new technology. They are less likely to grow wheat following either cereal crops or a pasture (Table 1). They are more likely to use and trust a fee-for-service agronomist, and to have a university education.

Table 1. Preceding crops before wheat crop and average nitrogen applied

	% of farms		Nitrogen application	
	High relative yield group (%)	Low relative yield group (%)	High relative yield group M (SD) (kg N/ha)	Low relative yield group M (SD) (kg N/ha)
A cereal crop	37***	65***	79 (51)*	57 (42)*
A canola crop	44	48	116 (146)**	58 (45)**
A pulse crop	62	53	75 (61)***	42 (34)***
A pasture phase	22***	44***	64 (58)**	30 (33)**

Note. The asterisk symbol indicates the statistical significance level of the differences between high and low relative yield groups, * $p < .05$, ** $p < .01$, *** $p < .001$.

Simulation study

We conducted a simulation study on the impact of sub-optimal management practices at 50 weather stations that span the whole grain zone (Figure 2). A benchmark "best management practice" was defined by: zero tillage with clean fallows and stubble retained; a non-limiting supply of nitrogen to the crop; sowing at 150 plants/m² was activated between 26 April and 15 July with 30 mm of plant available water (PAW) and a 15 mm cumulative rain event occurred over any 3 consecutive days. Table 2 shows the average national impact, relative to water-limited yield potential (Yw), of selected sub-optimal management practices.

Nationally, the average rate of N applied to grain crops is 45 kg N/ha (Angus and Grace, 2017). This one practice is sufficient to account for a 40% yield gap. Even at double that rate, a 23% yield gap remains. Frost and heat stress accounted for yield losses of between 16% and 25% of Yw depending on the function used (two versions of the Bell et al., 2015 function were used due to uncertainty about the function's parameters). Failure to control weeds during the summer fallow could account for up to a 26% yield loss; delayed sowing accounted for a 7% yield loss and low seedling density for an 8% yield loss. Any grower who is still practising conventional tillage could be missing out on 33% of their yield potential. Other factors that contribute to the yield gap, not included in simulations, include biotic stresses such as plant diseases, insects and other pests, in-crop weeds and extreme weather events (e.g. floods, strong winds and hail).

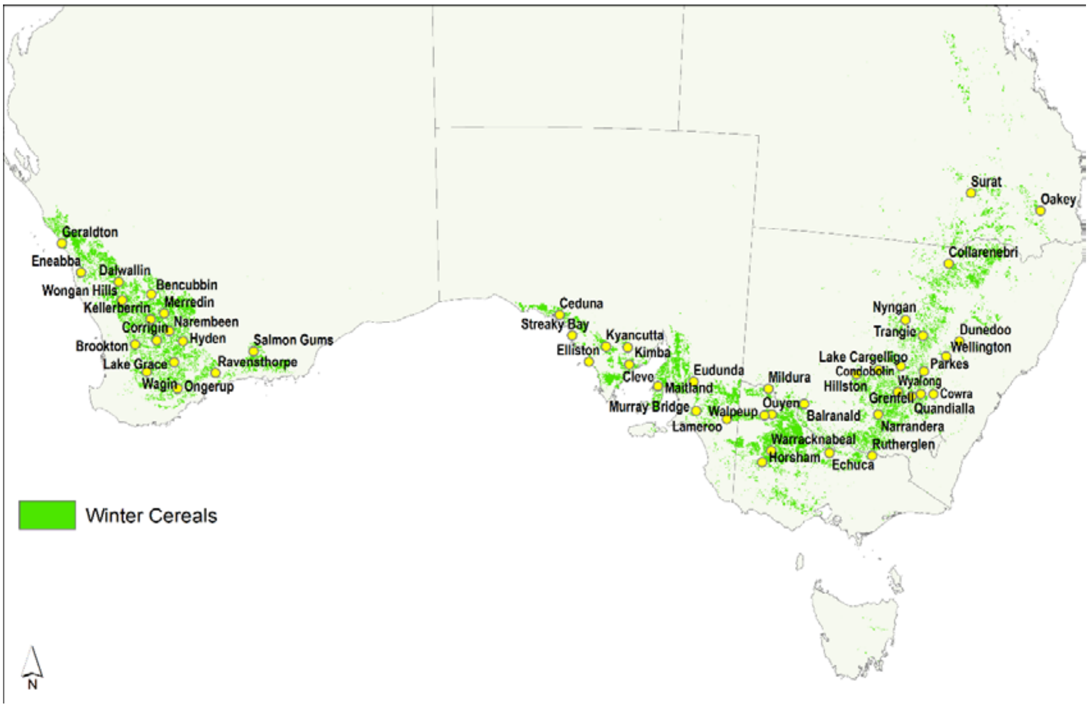

Figure 2. Fifty high quality weather stations and their distribution in Australia's cropping zone

Table 2. Impacts of management factors (treatments 2-7) and of frost and heat stress (treatments 9 & 10) on water-limited yield potential (Yw).

No	Treatment	Australian Grain Zone			Nyngan		Condobolin	
		Mean (t/ha)	SD (t/ha)	Y% (%)	Mean (t/ha)	Y% (%)	Mean (t/ha)	Y% (%)
1	Yw (water-limited yield)	4.28	0.92	100	2.78	100	3.44	100
2	Seedling density (50 plants/m^2)	3.78	1.10	88	2.68	96	3.11	90
3	Late sowing (2 week delay)	3.97	1.04	93	2.57	92	2.82	82
4	Summer weeds	3.18	1.17	74	1.66	60	2.89	84
5	Conventional tillage	2.86	1.08	67	2.35	84	2.18	63
6	N fertiliser (45 kgN/ha)	2.57	0.44	60	2.44	88	2.47	72
7	N Fertilizer (90 kgN/ha)	3.30	0.96	77	2.67	96	2.80	82
9	Frost and Heat	3.15	1.00	74	1.83	66	2.29	67
10	Frost and Heat 2 (moderate impact)	3.60	0.95	84	2.24	81	2.75	80

Two of the 50 stations of Figure 2 were located less than 100 km from Narromine and their results are summarised alongside the national results in Table 2. In Nyngan, which had a 15 year average Yw of 2.78 t/ha using the 'best management' parameters, the impact of only applying 45 kg N/ha was to restrict yields to 88% of Yw; failure to control weeds during the summer fallow could restrict yield to 60% of Yw; and a two week delay in sowing restricts yield to 92% of Yw; frost and heat stress accounted for yield losses of between 19% and 34% of Yw, depending on the function used. In Condobolin, which had a 15 year average Yw of 3.44 t/ha, the impact of only applying 45 kg N/ha was to restrict yields to 72% of Yw; failure to control weeds during the summer fallow could restrict yield to 84% of Yw; and a two week delay in sowing restricted yield to 82% of Yw; frost and heat stress accounted for yield losses of between 20% and 33% of Yw, depending on the function used.

We investigated some emergent management rules based on the idea of early sowing and matching the earlier time of sowing with slower maturing varieties that will best exploit the longer growing season as well as the need for new N fertiliser rules that will allow crops to fully exploit the additional yield potential due to the longer growing season. We found that in most locations the ideal sowing date was earlier than 26 April with a late maturing cultivar. This "emergent Yw" treatment, with a 15 year national average water-limited yield potential of 6.0 t/ha, had a 30% yield advantage over Yw and should be considered as the new yield frontier. While frost and heat stress reduce the yield potential of both Yw and the new simulated yield frontier, the advantage of the new treatment is slightly enhanced when frost and heat stress are taken into account. The advantage of early sowing combined with later maturing (slower developing) varieties is consistent with recently published field and simulation work for sites from Dubbo south to Victoria, and west to SA and WA (Flohr et al., 2017) but will require flexible additional application of N fertiliser to meet crop N requirements when seasonal conditions are right (e.g. seasons like 2016).

Risk-adjusted profit

Growers generally do not seek to maximise yield but rather to maximise their profit. However, growers are also generally averse to risk, meaning that profits should be adjusted for yield and price risk via a measure of certainty equivalent. The certainty equivalent represents the smallest amount of certain money a farmer is willing to receive to forgo an uncertain profit, and can be calculated as the difference between average profit and a risk premium (e.g. Hardaker et al., 2004; Monjardino et al., 2015). When typical costs were built in to allow profit and risk-adjusted profit to be calculated for a risk-neutral and a moderate risk-averse context, respectively (Figure 3), we found that despite the emergent Yw treatment providing the highest water-limited yield potential, the higher costs and risks associated with the additional N required meant that both maximum profit and maximum risk-adjusted profit were achieved by the optimised time of sowing by variety (OptTOS+var) treatment.

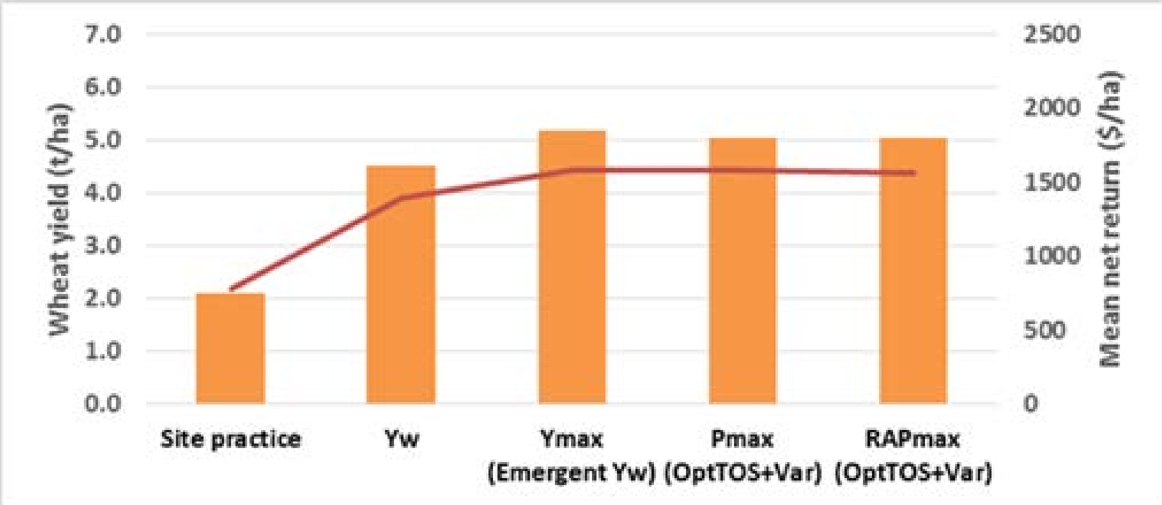

Figure 3. Wheat yield (t/ha) (orange bars) and net returns ($/ha) (red line) achieved by average site practice, water-limited yield potential (Yw), yield-maximizing (Ymax) practice (emergent Yw), and profit-maximizing (Pmax) and risk-adjusted profit maximizing (RAPmax) practices that are OptTOS+Var treatments at a medium yielding site (Enabba, WA).

Conclusions

There is ample room for central western growers to close the yield gap by adopting flexible non-limiting N fertiliser practices, by timely sowing and by controlling fallow weeds. For those growers who have already closed the exploitable yield gap by consistently achieving over 80% of Yw, simulation analysis suggests that the yield frontier can be raised by sowing wheat earlier than 26 April with slow maturing varieties. For middle yielding parts of Australia's grain zone, this practice has the potential to lift the production frontier by 19% and significantly improve risk-adjusted profitability. This finding needs to be fully evaluated in local field experiments.

Acknowledgements

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Making more reliable decisions on weather and soil water - case studies using CliMate and the SoilWater app.

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Notes

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.

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.**

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
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Table 3. Explanatory notes for product windows in all regions

<table>
<tr><th>Insecticide</th><th>Number of insecticide windows</th><th>Duration of insecticide windows</th><th>Maximum number of applications/crop/season</th></tr>
<tr><td>Chlorantraniliprole (Altacor®)</td><td>2</td><td>10 weeks</td><td>1</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>Indoxacarb (e.g. Steward®)</td><td>Northern - 3
Central - 2</td><td>6 weeks</td><td>1</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>Bacillus thuringiensis</td><td rowspan="3">1</td><td rowspan="3">Season long</td><td>No restrictions</td></tr>
<tr><td>Helicoverpa viruses</td><td>No restrictions</td></tr>
<tr><td>Spinetoram (e.g. Success Neo®)*</td><td>2</td></tr>
<tr><td colspan="4">Low resistance risk and not widely used.</td></tr>
<tr><td>Emamectin benzoate (e.g. Affirm®)*</td><td>1</td><td>Season long</td><td>2</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>Carbamates</td><td rowspan="2">1</td><td rowspan="2">Season long</td><td rowspan="2">1</td></tr>
<tr><td>Synthetic pyrethroids</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

*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. Whilst this is currently inconsistent with the Altacor label (2 applications per crop), we expect that there will be changes to the label to ensure consistency in these recommendations.

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 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 is already well established, relatively stable moderate-high levels of resistance to these MoAs, and limiting their use will not change this situation.

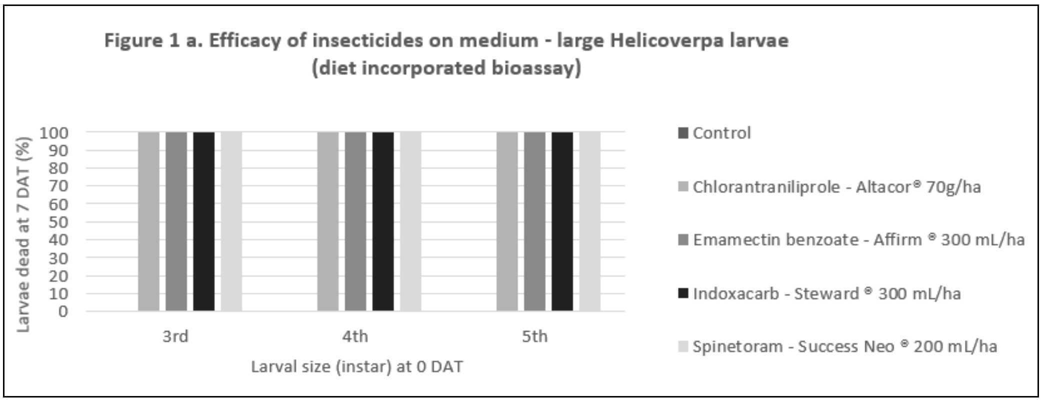
By restricting the use of just the 'at risk' products, keeping the RMS as simple as possible, and allowing maximum choice of registered products we anticipate that the grains industry will be more inclined to use the RMS.

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 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 (www.thebeatsheet.com.au).



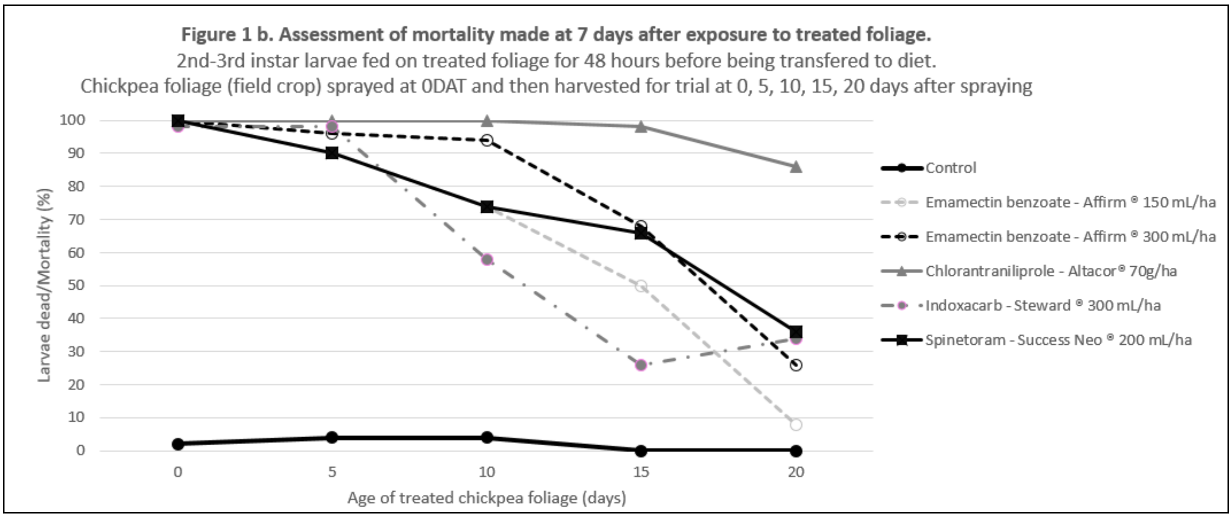


Figure 1. Relative efficacy (a) direct contact and (b) residual, of softer options for Helicoverpa control in chickpea and mungbean crops.

Rutherglen bug build up in canola – population dynamics during the 2017 season

In recent seasons, higher densities of Rutherglen bug (RGB) have been experienced. One of the challenges of this higher RGB pressure has been the movement of large numbers of nymphs from canola stubble into neighbouring summer crops. Through sheer weight of numbers, RGB nymphs can kill sorghum, cotton, soybean, corn and sunflower plants in the rows closest to canola. The movement of nymphs can occur over a period of weeks, and even regular spraying of the affected crops may not prevent significant crop loss.

Understanding how these enormous populations of nymphs develop is key to working out how they might be prevented, or managed, so that they don't affect neighbouring summer crops. Rather than focusing on controlling the nymphs, we were interested in whether there may be an opportunity to control the adults before they reproduce. During the spring of 2017, QDAF entomology monitored a number of canola crops, from the Darling Downs to the Liverpool Plains. We assessed the density of adults in the canola, dissected females to determine if they were reproductive (laying eggs), and assessed the crops for nymphs. We also attempted to determine the timing of egg laying by assessing the density of eggs – however, we were unable to do this effectively. Other than determining that eggs are deposited in the soil and on the leaf litter on the soil surface (not in the crop canopy), we could not reliably assess egg density.

Whilst this is only one season of data, it is presented here to highlight the following key findings.

RGB adults were present in the canola crops much earlier than we expected (Figure 2). Even at the most southerly site (Curlewis, NSW), RGB adults were present in canola from early August. At most sites, numbers increased through September and October.

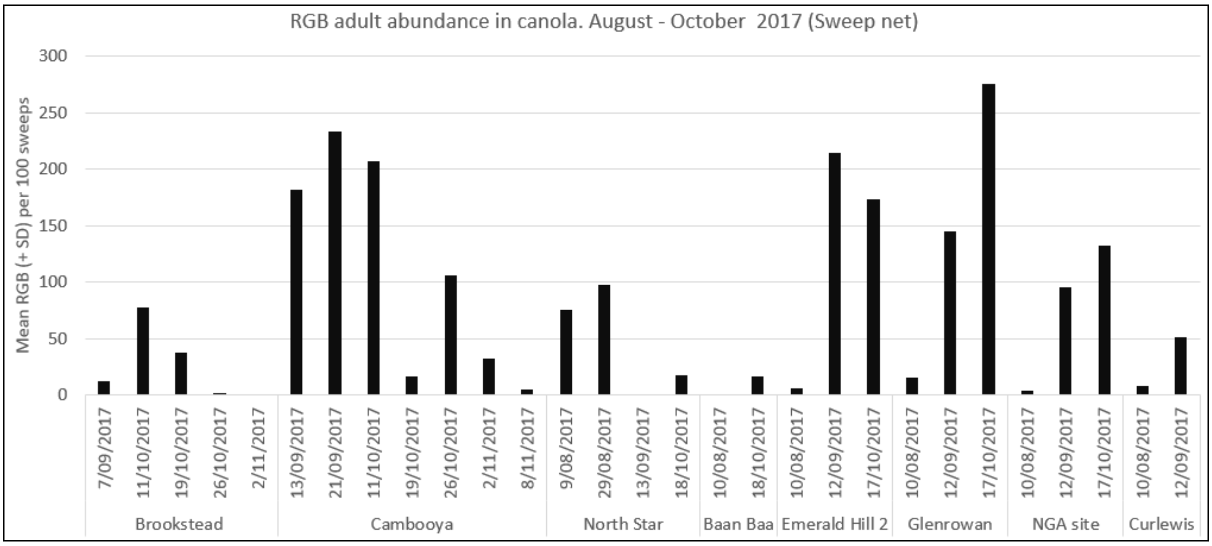


Figure 2. RGB adults were present in canola from late winter (August – September). (SD = standard deviation)

Female RGB were reproductive (had mature eggs in their ovaries ready to lay) from September onwards, and the percentage of the population that was reproductive increased from September through November (Figure 3).

Although the majority of female RGB were reproductive, and laying eggs, we did not see nymphs start to emerge until much later than expected based on the day degrees accumulated during this period (Figure 4).

It is possible that the development of eggs is slowed by the relatively cool temperatures experienced on the soil surface under the leaf litter and crop canopy. When the crop is harvested or windrowed, the temperature of the soil quickly rises, potentially resulting in synchronous hatching of eggs that have been laid over a period of 2-3 months.

More data is needed over additional sites and seasons to confirm our theory, and closer monitoring of soil temperature and RGB egg development is also needed to understand exactly what is happening.

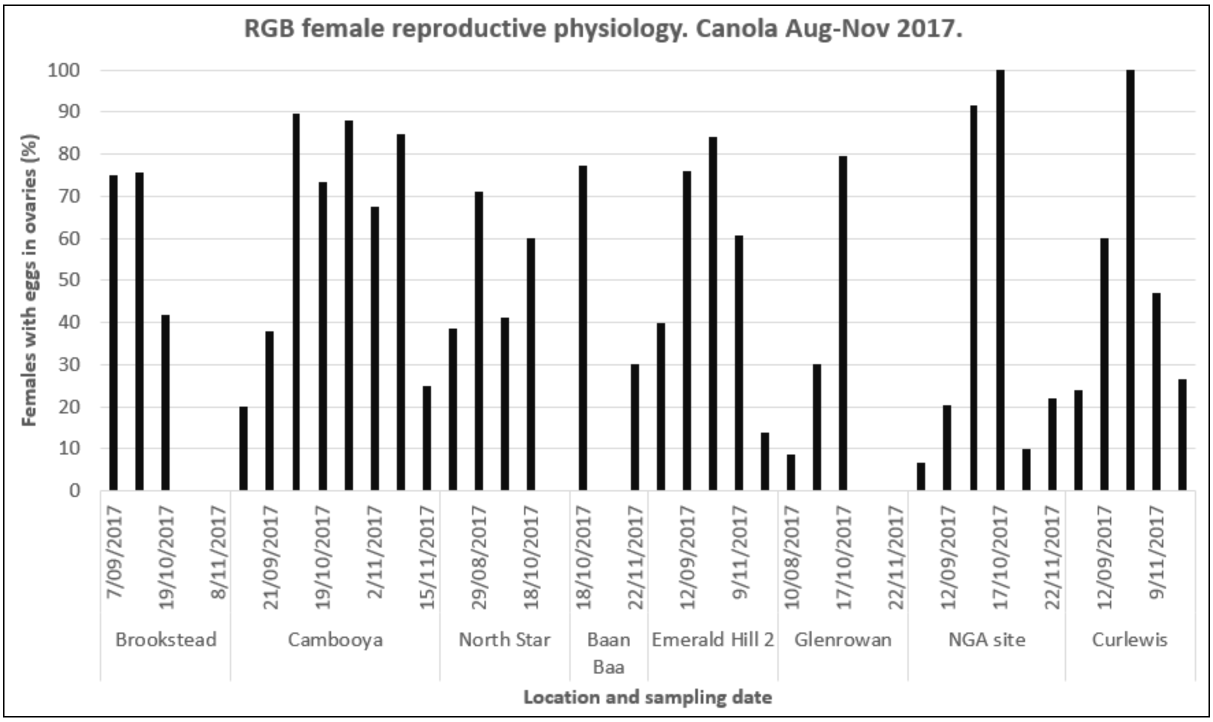


Figure 3. A high proportion of the female RGB sampled were laying eggs from September through November.

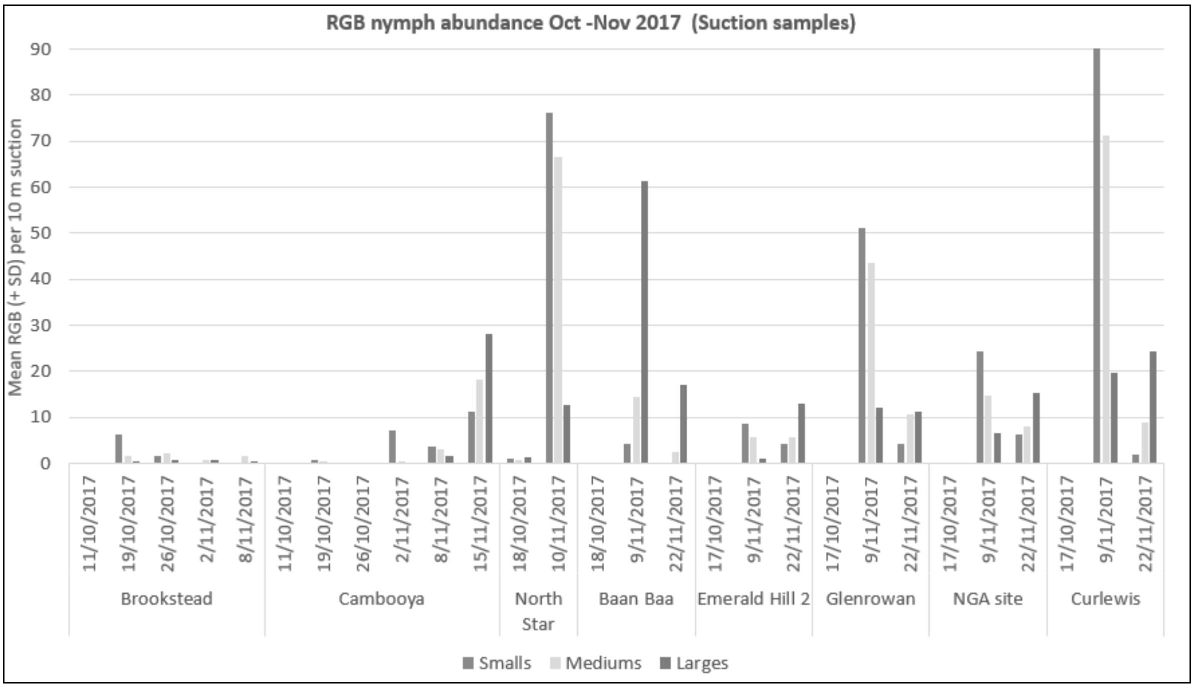


Figure 4. Nymphs did not start to emerge until much later than expected based on the day degrees accumulated during this period, despite the majority of female RGB being reproductive and laying eggs.

The take home message from this RGB work is that there doesn't seem to be an easy fix to prevent the build-up of RGB nymphs in canola stubble. The long period of egg laying by the females, and the potential challenges with controlling nymphs on the ground under the crop canopy, means that there is no obvious opportunity to prevent the population build up.

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.

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

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Site-specific physical weed control

Michael Walsh and Guy Coleman, University of Sydney

Key words

physical weed control, site-specific weed management, energy requirements

GRDC code

US00084

Take home messages

- Developments in sensing technology will soon allow the direct targeting of weeds within cropping systems
- Site-specific weed control creates the opportunity to use alternate physical weed control technologies
- Energy required to effectively control weeds is an effective approach to identifying suitable physical weed control techniques

Background

The reliance on herbicidal weed control has resulted in the widespread evolution of herbicide-resistant weed populations (Boutsalis et al., 2012; Broster et al., 2013; Owen et al., 2014). Changing regulations and expensive herbicidal development costs combined with the perennial threat of herbicide resistance, ensures future effective weed control is reliant on the inclusion of alternate weed control technologies in weed management programs. Physical weed control techniques were in use well before herbicides were introduced and the development of new options has continued throughout the era of herbicides. However, most of these new technologies have not been adopted, primarily due to cost, speed of operation and fit with new farming systems. The introduction of weed detection and actuation technologies creates the opportunity to target individual weeds i.e. site-specific weed management. This greatly increases the potential cost-effectiveness of many directional physical weed control techniques in conservation cropping systems.

Comparison of physical weed control technologies

There is a diverse array of effective physical weed control options with a proven ability to control weeds. The majority of these have not been commercialized and evidence of their efficacy relates to research findings, making cost-effectiveness comparisons difficult. While inputs and control methods differ significantly between physical control options, all systems share an energy requirement value for activation and use. Therefore, the energy required for effective weed control can be a reasonably accurate approach to comparing the efficiency and efficacy of physical control systems on an energy consumed per weed or hectare basis.

The direct energy requirements for the control of two-leaf weed seedlings were estimated from published reports on the weed control efficacy of a comprehensive range of physical weed control techniques (Table 1). To determine the energy requirement per unit area, a weed density of 5.0 plants m^{-2} was chosen to represent a typical weed density in Australian grain fields, based on results from a recent survey of Australian grain growers (Llewellyn et al., 2016).

Broadcast weed control

Broadcast weed control is defined as the indiscriminate use of a control method on a whole paddock basis when controlling weeds within crops or in fallow situations.

Chemical weed control

Herbicides are the most commonly used form of weed control in global cropping systems primarily due to their high efficacy and reliability. Herbicides are highly cost effective and have a relatively low energy cost of approximately 220 MJ ha^{-1}, covering manufacture and application. Importantly, herbicides remain the only broadcast weed control option that provides highly selective in-crop weed control and, therefore have been critical to the adoption of highly productive conservation cropping systems. No other currently available form of weed control offers similar weed control efficacy with equivalent crop safety.

Physical weed control

Historically, tillage was relied on for weed control as well as seedbed preparation and continues to be used extensively in global cropping systems despite the extensive reliance on herbicides. As a group, soil disturbance-based options are the most energy efficient form of physical weed control (Table 1) with no additional energy inputs beside the draft force requirements. Tillage acts to control weeds by uprooting plants, severing roots and shoots and/or burial of plants. Consequently, the efficacy and impact of this approach is reliant on rainfall and soil moisture. Effective control can only be achieved when disturbed weeds are exposed to a drying environment after the tillage operation. Although tillage can be a highly effective weed control option the soil disturbance involved is not compatible with conservation cropping systems and, therefore this approach needs to be used sparingly.

There are a group of thermal weed control technologies (flaming, hot water foaming and steaming etc.) using chemical or electrical energy that may be used for broadcast weed control (Table 1). In comparison to tillage and herbicide-based options these approaches are considerably more energy expensive. With 100 to 1000-fold higher energy requirements it is not surprising that these technologies have not been widely adopted for use in large-scale cropping systems, although in more intensive operations flaming is used to some extent.

Table 1. Total energy requirement estimates for physical weed control options currently available for broadcast application. Estimates are based on the control of two-leaf weeds present at 5 plants m^{-2}.

Weed control method	Energy consumption ($MJ\ ha^{-1}$)
Plastic mulching	3
Flex tine harrow	4
Sweep cultivator	11
Rotary hoe	13
Organic mulching	16
Rod weeding	18
Spring tooth harrow	22
Basket weeder	29
Roller harrow	29
Disc mower	31
Tandem disk harrow	36
Flail mower	57
Offset disk harrow	64
UV	1701
Flaming	3002
Infrared	3002
Hot water	5519
Hot foam	8339
Steam	8734
Freezing	9020
Hot air	16902
Microwaves	42001

Site-specific weed control

The opportunity for substantial cost savings and the introduction of novel tactics are driving the future of weed control towards site-specific weed management. This approach is made possible by the accurate identification of weeds in cropping systems using machine vision typically incorporating artificial intelligence. Once identified, these weeds can be controlled through the strategic application of weed control treatments. This precision approach to weed control creates the potential for substantial cost savings (up to 90%) and the reduction in environmental and off-target impacts (Keller et al., 2014). More importantly for weed control sustainability, site-specific weed management creates the opportunity to use alternate physical weed control options that currently are not suited for whole paddock use.

Accurate weed detection allows physical weed control treatments to be applied specifically to the targeted weed. As weed identification processes develop to include weed species, size and growth stage, there exists the potential for some approaches (such as electrical weeding, microwaving and lasers) to be applied at a prescribed lethal dose. This dramatically reduces the amount of energy required for effective weed control (Table 2). For example, microwaving, as the most energy expensive weed control treatment as a broadcast treatment (42,001 MJ ha^{-1}), requires substantially less energy when applied directly to the weed targets (3.4MJ ha^{-1}). Thus, even though the same number of weeds are being controlled (5 plants m^{-2}) the specific targeting of these weeds results in a 99% reduction in energy requirements.

The accurate identification of weeds allows the use of alternate weed control technologies that are not practically suited for use as whole paddock treatments. For example, lasers are typically a narrow beam of light that is focussed on a point target. In a site-specific weed management approach with highly accurate weed identification and actuation, lasers can be focussed precisely on the growing points of targeted weeds, concentrating thermal damage. By reducing the treated area of the weed, off-target losses are further reduced allowing additional energy savings.

Table 2. Total energy requirement estimates for physical weed control options when used for site-specific weed control treatment. Estimates are based on the control of two-leaf weeds present at 5 plants m^{-2}.

Weed control method	Energy consumption ($MJ\ ha^{-1}$)
Concentrated solar radiation	0.0
Precise cutting	0.01
Pulling	0.01
Electrocution: spark discharge	0.1
Nd:YAG IR laser pyrolysis*	0.7
Hoeing	1.3
Water jet cutting	1.4
Stamping	2.1
Nd:YAG IR laser pyrolysis*	2.5
Microwaves	3.4
Abrasive grit	10
Thulium laser pyrolysis*	12
CO_2 laser cutting*	40
Targeted flaming	46
Electrocution: continuous contact	47
Nd:YAG laser pyrolysis*	70
CO_2 laser pyrolysis*	78
Nd:YAG UV laser cutting*	115
Hot foam	117
Dioide laser pyrolysis*	119
Nd:YAG IR laser cutting*	190
Targeted hot water	503

* Different laser weeding systems

Conclusions

By using energy requirements as a level playing field for comparison, the various efficiencies of each control method became more apparent. Furthermore, this approach enabled a better understanding of site-specific opportunities for physical weed control. Targeting treatments on individual plants results in significant energy savings and makes previously impractical options on a broadcast basis, available for use on a site-specific basis. The opportunities here are immense for the future management of problem weeds.

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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The efficacy of chaff lining and chaff tramlining in controlling problem weeds

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Key words

Chaff lining, chaff tramlining, harvest weed seed control, annual ryegrass, brome grass, wild oats, wild radish, turnip weed, common sowthistle

GRDC code

US00084 (Innovative Crop Weed Control for Northern Region Cropping Systems)

Call to action/take home messages

- Use chaff lining or chaff tramlining concentrates weed seeds into a narrow area.
- A heavy layer of chaff will lead to better suppression of weed emergence.
- Small seeded broadleaf weeds (e.g. common sowthistle) are more easily suppressed than grass weeds with larger seeds (e.g. annual ryegrass).
- Thick tramlines and chaff lines reduce but do not prevent weed emergence, so other measures may be needed to control weeds in tramlines/chaff lines (e.g. spraying the tramlines with a shielded sprayer).

Background

Herbicide resistance is a major concern for northern region crop production due to the increasing frequency of resistance in key weeds. Of particular concern is the increasing incidence of glyphosate resistance, with 9 weed species now confirmed as glyphosate resistant in the northern region (Heap, 2018). Regardless of the ever-increasing frequency of herbicide-resistance, herbicides will likely remain the most effective form of weed control in cropping systems. However, for herbicides to remain effective, non-herbicide weed management alternatives are needed to delay the spread and onset of further herbicide resistance (Walsh et al., 2013). One such alternative is harvest weed seed control (HWSC).

In this paper we report on research evaluating the effectiveness of chaff tramlining and chaff lining as harvest weed seed control tactics for northern region weeds.

Chaff lining and chaff tramlining are forms of harvest weed seed control (HWSC) that have potential for widespread adoption in northern Australia owing to their relative low cost and ease-of-implementation. Chaff tramlining is the practice of concentrating the weed seed bearing chaff material on dedicated tramlines in controlled traffic farming (CTF) systems. Chaff lining is a similar concept, where the chaff material is concentrated in a narrow row between stubble rows directly behind the harvester. The chaff environment is likely to be suboptimal for seed persistence and seedling establishment, therefore, this practice has the potential to be as effective as other forms of harvest weed seed control in depleting weed seed banks.

Aim

To evaluate the influence of different amounts and types of chaff on weed seedling emergence.

Method

Pot experiments were conducted at Narrabri and Toowoomba. There were some variations on the method used at each location (i.e. type and dimensions of experimental unit e.g. pot versus trays), but the basic method involved 4 replicates of each experimental unit (pot or tray filled with potting mix and sown with either 100 or 200 weed seeds on the surface), with 8-9 rates of chaff (either wheat or barley). A pre-weighed layer of chaff was added to the surface of each pot at the equivalent rates of 0, 3, 6, 12, 18, 24, 30, and 42 t/ha. Once the chaff was evenly spread across the soil surface, the pots were watered thoroughly and kept moist for 28 days, over which time weed emergence was recorded. Differences between chaff types and rates were assessed using the total germination over a 28 day period.

The chaff rates used in the pot experiments were designed to mimic the rates of chaff that may occur in a field situation. To calculate the rates of chaff that might be expected in a field situation, the following formula was used:

Y = 0.3 x Z x (harvester width/tramline width)

Where Y = chaff yield and Z = grain yield of wheat

Note: assuming chaff yield is 30% of grain yield

This formula is based on previous experimentation in wheat (data not shown), where chaff yield was determined to represent approximately 30% of the grain weight. For example, using a wheat yield of 3.5 t/ha, a 12m harvester width and a 30cm chaff line width, the amount of chaff concentrated into a chaff line would be 42 t/ha.

Statistical analysis

The treatments used in the Narrabri pot experiment were 8 rates of wheat chaff laid out in a randomised complete block design with four replicates to explore emergence of annual ryegrass. The Toowoomba-based pot experiment was a factorial combination of eight rates by two chaff types (wheat and barley) by two weed species (annual ryegrass and common sowthistle), also laid out in a randomised complete block design with latinisation of the treatment.

The emergence data from both the Toowoomba and Narrabri pot experiments were transformed using angular (or arcsine) transformation and predictions back-transformed. The data were analysed using ANOVA or REML procedure in Genstat 19th Edition (VSN International, 2017). In the analysis of the Toowoomba-based pot experiment the rate and chaff type treatments were partitioned for each weed species. The level of significance was set at 5% for all testing. The protected least significant test (LSD) was used for pair-wise comparisons of significant treatment effects.

Results and discussion

Annual ryegrass

In both the Narrabri (Figure 1) and Toowoomba (Figure 2) pot experiments; there was a consistent reduction in annual ryegrass emergence with increasing amounts of wheat chaff. More detailed results including the LSDs used to compare treatments are presented in the Appendix. Relative to the zero chaff treatment, emergence of annual ryegrass was reduced by the presence of wheat chaff at rates equal to and over 18 t/ha and 24 t/ha in the Narrabri and Toowoomba experiment, respectively.

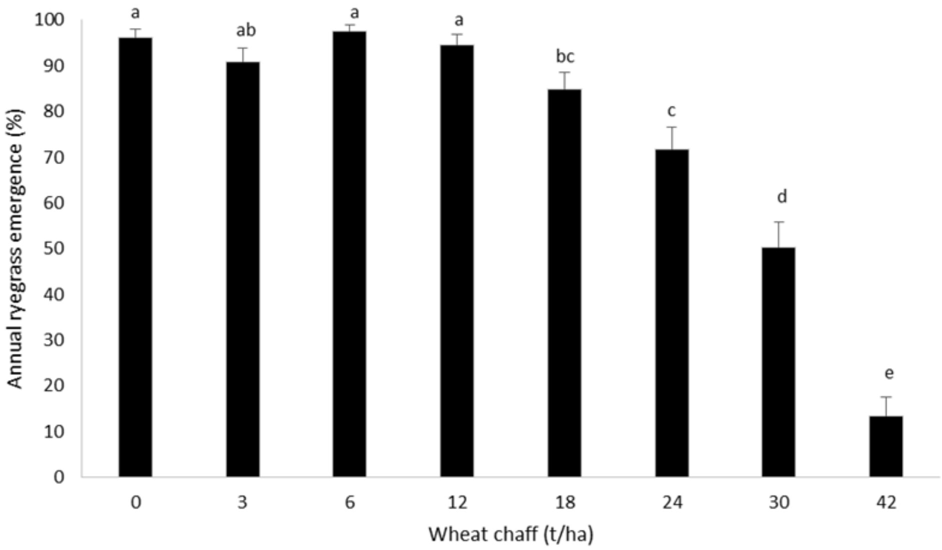

Figure 1. Emergence of annual ryegrass through wheat chaff at 8 different rates (t/ha) in a pot experiment conducted at Narrabri, NSW

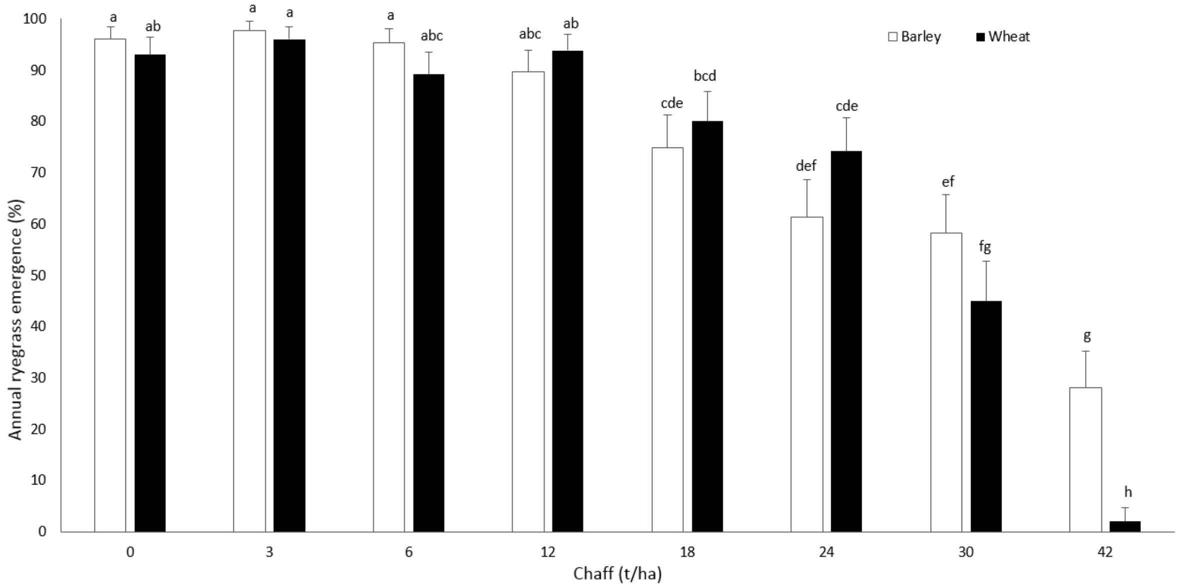

Figure 2. Emergence of annual ryegrass through barley and wheat chaff at 8 different rates (t/ha) in a pot experiment conducted at Toowoomba, QLD

There was an interaction between chaff amount (weight) and chaff type (barley vs wheat) on annual ryegrass emergence. There was no significant difference between chaff types at rates = 0, 3, 6, 12, 18, 24 and 30 t/ha. At 42 t/ha of barley chaff there was greater annual ryegrass emergence than at the same amount of wheat chaff (Figure 2).

At the greatest chaff rate (42 t/ha), annual ryegrass emergence from wheat chaff was 14% in the Narrabri experiment and 2% in the Toowoomba experiment. In the case of barley chaff, emergence was much greater (28%) at the 42 t/ha chaff rate. The Toowoomba pot experiment is currently being repeated to confirm the results of the first experiment and an additional greater chaff amount (60 t/ha) treatment is being used.

Common sowthistle

Emergence of common sowthistle declined sharply with increasing amounts of chaff at rates equal to and exceeding 12 t/ha (Figure 3). More detailed results including the LSD used to compare treatments are presented in the Appendix. There were significant main effects of chaff type and chaff rate, but no significant interaction (for this reason, data are combined for both chaff types). Overall, there was higher sowthistle emergence from beneath barley chaff (49.0%) compared with wheat chaff (40.6%). There was no difference between the chaff rates at 0, 3 and 6 t/ha, but emergence was reduced at all higher chaff amounts. Common sowthistle emergence was almost completely suppressed (0.02% emergence) at the heaviest chaff amount (42 t/ha).

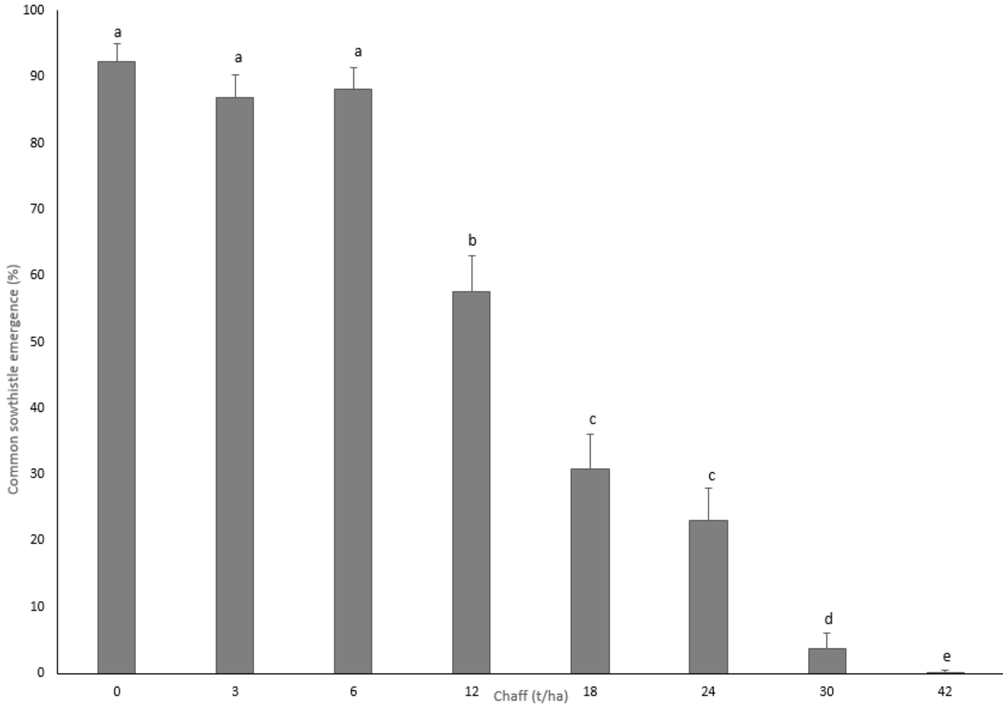

Figure 3. Emergence of common sowthistle through barley and wheat chaff (combined data) at 8 different rates (t/ha) in a pot experiment conducted at Toowoomba

The difference in emergence responses of the two weed types is likely due to the larger seed size of annual ryegrass, providing the seedlings with greater energy reserves to grow through deeper layers of chaff to reach light. An alternative suggestion is that, relative to grasses, the broad leaf structure of sowthistle seedlings renders them less capable of penetrating through chaff layers. These two reasons could work in combination to render common sowthistle more susceptible to smothering by chaff layers, relative to annual ryegrass.

Conclusions

The results of these pot studies indicate that emergence of common sowthistle will be better suppressed than annual ryegrass under similar amounts of chaff.

Relative to barley chaff, wheat chaff had a greater suppressive effect on the emergence of annual ryegrass seedlings. This could be due to structural or chemical (allelopathic) differences between the chaff types and will be the subject of further research over the next 6-12 months.

In a chaff tramlining system chaff material is deposited on both tramlines, and therefore each tramline will have only half the amount of material than is concentrated in a single chaff line. For this reason, chaff lining may be more effective than tramlining in achieving weed suppression, owing to the greater concentration of chaff in one line versus 2 lines.

In summary, using tramlining or chaff lining can considerably reduce weed emergence given sufficiently high chaff loads. Because chaff tramlining/chaff lining will concentrate the weed seeds into narrow strips, the bulk of the seed bank is distributed over a small area favouring the use of more efficient and targeted chemical/mechanical approaches.

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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Appendix

Table 1. Predictions of annual ryegrass emergence through wheat chaff at 8 different rates (t/ha) from a pot experiment conducted at Narrabri. These are back-transformed means (figures in brackets are the transformed means). The protected least significant test was used for pair-wise comparisons of significant treatment effects on the transformed scale (LSD = 9.43).
NB: Means with the same letter are not significantly different at the P = 0.050 level.

Chaff rate t/ha	Emergence
0	96.2% (78.8) a
3	90.9% (72.4) ab
6	97.5% (81) a
12	94.6% (76.6) a
18	84.8% (67) bc
24	71.6% (57.8) c
30	50.2% (45.1) d
42	13.5% (21.5) e

Table 2. Predictions of annual ryegrass emergence through barley and wheat chaff at 8 different rates (t/ha) from a pot experiment conducted at Toowoomba. These are back-transformed means (figures in brackets are the transformed means). The protected least significant test was used for pair-wise comparisons of significant treatment effects on the transformed scale (LSD = 12.3).
NB: Means with the same letter are not significantly different at the P = 0.050 level.

Chaff rate t/ha	Barley	Wheat
0	96% (78.5) a	93% (74.6) ab
3	97.7% (81.3) a	96% (78.5) a
6	95.3% (77.5) a	89.1% (70.8) abc
12	89.7% (71.2) abc	93.8% (75.6) ab
18	74.8% (59.9) cde	80% (63.5) bcd
24	61.3% (51.5) def	74.2% (59.5) cde
30	58.3% (49.8) ef	44.9% (42.1) fg
42	28% (32) g	2% (8.1) h

Table 3. Predictions of sowthistle emergence through barley and wheat chaff (combined data) at 8 different rates (t/ha) from a pot experiment conducted at Toowoomba. These are back-transformed means (figures in brackets are the transformed means). The protected least significant test was used for pair-wise comparisons of significant treatment effects on the transformed scale (LSD = 8.698).
NB: Means with the same letter are not significantly different at the P = 0.050 level.

Chaff rate t/ha	Emergence
0	92.3% (73.85) a
3	86.9% (68.75) a
6	88.1% (69.83) a
12	57.6% (49.38) b
18	30.8% (33.69) c
24	23.1% (28.73) c
30	3.6% (11.01) d
42	0.02% (0.88) e

Harvest weed seed control – beyond windrow burning

Greg Condon and Kirrily Condon
Grassroots Agronomy & Australian Herbicide Resistance Initiative

Keywords

weed seed banks, integrated weed management (IWM), herbicide resistance, annual ryegrass, wild radish, harvest weed seed control (HWSC), narrow windrow burning (NWB), chaff cart, chaff lining, chaff decks, Integrated Harrington Seed Destructor (iHSD)

Take home messages

- Harvest weed seed control (HWSC) comes in many forms – bale, burn, graze, mill or rot
- Match the harvest weed seed control tactic to your farming system, crop types and location
- Capturing weed seeds in the chaff fraction when chaff lining or using chaff decks requires attention to detail in harvester setup
- Harvest weed seed control cannot be used effectively in isolation – adopt the 'big six' and top shelf agronomy to drive weed numbers to zero

Background

Herbicide resistance remains an ongoing challenge for Australian grain growers but the industry is continually innovating to minimise the risks. Non-chemical tools are becoming mainstream practice so that growers and advisers can deal with herbicide resistance by reducing weed seed banks and protecting chemistry.

One of the most popular weed management tactics being adopted in recent years is harvest weed seed control (HWSC). This process takes advantage of seed retention at maturity by collecting weed seeds as they pass through the harvester. Problematic weeds such as annual ryegrass, brome grass and wild radish retain 77-95% of their seed above a harvest cut height of 15cm at maturity, creating an ideal opportunity for seed collection.

Seed retention will change over time with the proportion of retained weed seeds declining the longer harvest is delayed past crop maturity. Therefore, crop and weed maturity will have a significant impact on the success of harvest weed seed control. Harvest height is equally important for harvest weed seed control, with a 15cm cut height preferred to capture 80-90% of the ryegrass seed at maturity - this can be challenging in high yielding cereals or bulky hybrid canola crops.

In the southern cropping region, low harvest height has been a barrier to adoption with growers not wanting to slow harvest down, incurring higher fuel costs and reducing harvester efficiency. Growers and researchers have since been looking at tactics that will enhance the efficacy of harvest weed seed control without slowing harvest. One option being adopted is sowing crops at narrower row spacings or higher plant populations. Weeds are then forced to grow taller to compete for light, therefore producing seed higher in the crop canopy. Stripper fronts are also being investigated to gauge any differences with weed seed capture and harvest efficiency, reducing the need to cut low whilst minimising fuel consumption.

Harvest weed seed control (HWSC) practices

Originally pioneered 30 years ago with chaff carts in Western Australia, harvest weed seed control has now been adopted nationally as growers tailor their options to suit different farming systems and locations. The harvest weed seed control options are all slightly different with narrow windrow burning (NWB) and bale direct taking in both straw and chaff for burning or baling. Newer harvest weed seed control practices only take in the chaff fraction containing weed seeds for rotting, grazing or destruction through a mill. This includes chaff lining or chaff decks, chaff carts and emerging mill technology using the Integrated Harrington Seed Destructor (iHSD) or Seed Terminator.

Research by Walsh et. al., 2014 (https://ahri.uwa.edu.au/harvest-weed-seed-control-tools-they-all-work/) highlighted that harvest weed seed control tactics are equally effective in reducing weed seed production. The use of chaff carts, narrow windrow burning or the Integrated Harrington Seed Destructor, were compared at 24 sites across Australia with an average reduction in ryegrass of 60% germination the following autumn. This was achieved by removing 70-80% of the seed at harvest through either burning or destruction of weed seeds.

Research has recently commenced to gauge the impacts of chaff lining and chaff decks on the rotting of weed seeds under different crop types. Preliminary data suggests poor seed survival under canola or barley chaff because of an allelopathic effect; however in wheat there was high ryegrass seed survival underneath the chaff row which is unexplained. Michael Walsh from Sydney University and John Broster from Charles Sturt University are currently working to quantify the value of rotting under chaff line and chaff deck systems.

Each harvest weed seed control practice has its own benefits and challenges with growers leading the charge, working with a small group of researchers to develop harvester modifications that maximise weed seed control with harvest height and seed retention. For harvest weed seed control to be successful at the farm level the practice needs to be both cost effective and practical to fit in with existing operations.

Harvest weed seed control cannot be used in isolation for weed management; growers and advisers should implement a range of diverse weed management practices to drive weed numbers down. Defined as the ‘Big six’ (www.weedsmart.org.au/the-big-six), these management practices include diverse rotations, mix and rotating herbicides, crop competition, double knocks, crop topping/hay to stop seed set and harvest weed seed control. The ‘big six’ complements best practice agronomy such as calendar sowing combined with effective pre-emergent herbicide packages.

Harvest weed seed control adoption

An online twitter survey was conducted in November 2017 by WeedSmart with 269 growers responding. The results indicated that harvest weed seed control practices are changing, with narrow windrow burning declining at the expense of chaff lining and chaff decks. 32% of growers were planning to use narrow windrow burning in 2017 whilst 26% would be chaff lining and 9% using chaff decks. Chaff carts were stable at 13%, mill technology at 3% and 14% would be doing nothing.

The overall trend is positive and reflects the high value growers are increasingly putting on harvest weed seed control as a mainstream weed management tool, it does not come easy and looking at each practice in detail (table 1) highlights what growers and advisers need to be aware of.

Table 1: Harvest weed seed control options

Harvest weed seed control tactic	Indicative cost	Labour required	Crop residue removed	Positives	Negatives	Best fit
Narrow windrow burning	$200	Burning rows	Chaff & straw 40-100%	Low cost	Nutrient removal. Smoke. Fire escapes	Low rainfall, canola and pulses
Glenvar Bale Direct	$340,000	Pick up bales	Chaff & straw 40-50%	Profit from bales	Nutrient removal, cost	Market for bales
Chaff carts	$15,000-$80,000	Graze, burn heaps	Chaff only 15%	Feed value for sheep	Burning of piles	Mixed farmers
Chaff lining	$200 to $4500	Minimal	Chaff only 15%	Low cost, no burning, weed seeds left to rot	Insects & mice in chaff rows	Everywhere except small, windy paddocks; Suits both mixed farmers & intensive croppers
Chaff decks	$15,000 to $20,000	Minimal	Chaff only 15%	No dust on tramlines, no burning	Insects & mice in chaff rows, chaff rows driven over	CTF farmers both mixed and intensive croppers
Integrated Harrington Seed Destructor (iHSD)	$165,000	Minimal	0%	No loss of residue	Still in the development stages, cost	Intensive croppers
Seed Terminator	$100,000	Minimal	0%	No loss of residue	Still in the development stages, cost	Intensive croppers

Narrow windrow burning (NWB)

Developed in the northern WA cropping zone narrow windrow burning has been highly effective at reducing annual ryegrass and wild radish seed banks across the nation. A chute is attached to the back of the harvester to concentrate straw and chaff into a 500-600mm narrow windrow; these rows are then burnt the following autumn. The practice is low cost and highly effective with rows burning hotter for longer than a standard stubble burn. Up to 99% of weeds seeds are controlled in a well-managed hot burn where temperatures reach 400°C to 500°C for at least 10 seconds.

Despite its simplicity and popularity, the practice is now in decline due to several factors. Burning is the major challenge, especially if fire escapes from the rows to burn the whole paddock or trees. Rows becoming wet after summer rains can create challenges waiting for the rows to dry out for the fire to burn hot enough and destroy weed seeds. Nutrient redistribution and ground cover loss are also key issues for growers using narrow windrow burning, particularly on lighter soil types.

Smoke in built up rural communities has been problematic for narrow windrow burning, where smoke lingers late into the evening when wind inversions occur. Some growers are actively looking at alternative options to narrow windrow burning, whilst for those where the process works it will remain a key tool in their harvest weed seed control tactic toolbox.

Glenvar Bale Direct

Chaff and straw are collected during harvest then baled directly using a baler attached to the harvester. There is a moderate level of groundcover removal with straw and chaff removed, whilst weed seed removal is high. A large capacity harvester is needed to operate the baler but does not slow the harvesting operation down. Growers would require access to markets to utilise the bales for bedding or as a feed source.

Chaff carts

The first harvest weed seed control tactic tool introduced from Canada for the collection of chaff material for feeding to sheep. A cart is towed by the header which collects chaff and weed seeds then dumps it in piles for grazing or burning. The original blower delivery system was improved with a conveyor belt elevator which allows some small straw into the chaff fraction. The increased oxygen levels in the chaff has resulted in a quicker, hotter burn. Burning of chaff piles has created similar issues to narrow windrow burning with chaff piles smouldering for long periods.

New research is proving the value of chaff dumps not only for weed seed reduction but also sheep feed (https://ahri.uwa.edu.au/chaff-carts-good-for-the-crop-and-the-sheep/). Chaff piles can be grazed by sheep directly or baled for sale into feedlots or other associated markets. Ed Riggall is a sheep consultant from WA who has found that sheep grazing chaff piles gained 3kg/head more over three weeks than those without chaff piles. This was despite the sheep taking one week to get used to the chaff piles. Chaff piles are reducing supplementary feeding costs and increasing scanning results while reducing weed seed numbers. Studies have shown that sheep do not spread weed seeds, with only 3-6% of seed remaining viable after passing through the rumen. Cattle are less effective at destroying ryegrass seed with 15-20% of the seed remaining viable.

Chaff lining

Developed by Esperance grain growers, chaff lining involves separation of the chaff and weed seed fraction from the straw residue, with chaff dropped into a narrow line behind the harvester via a chute attached to the main sieve. The chaff line remains on the soil surface where weed seeds are left to rot, while the straw travels through the rotor to be chopped and spread.

Chaff lining is repeated on the same runs year after year to allow weeds to continually rot in a defined area. There is limited research data to quantify the full impacts of seed rotting but observations to date indicate the undisturbed chaff row is a hostile environment for weed seeds. Growers don’t need to be on a full controlled traffic farming system but ideally the header needs to run on the same lines each year.

Chaff lining is low cost, involves no burning and growers have the option to graze chaff lines with similar feed values as that found with chaff carts. Chaff lines have been successfully grazed in stubble over summer but also in winter when sown to a dual-purpose grazing crop.

Harvester setup is critical to maximise weed seed capture with growers adding a separating baffle above the sieves to ensure chaff stays out of the straw and exits via the chute. Grain needs to be threshed hard to get weed seeds out of the head, with the grates of the harvester opened up to get as much material out of the rotor and onto the sieve for collection.

Growers have built their own chutes and baffles to suit a wide range of harvesters with 2017 being the first season many growers adopted the practice. There were several situations where chaff lining setups caused issues at harvest including a build-up of excess fine chaff on the air cleaner or blockages at the rear of the baffle in canola. Refinements to chaff lining are ongoing as growers work with each other and industry to achieve continuous improvement with the practice.

Chaff decks

The chaff deck system operates on a similar principle to chaff lining but the chaff material is directed onto dedicated wheel tracks in a control traffic farming (CTF) system. Known also as chaff tramlining and developed in the Esperance region of WA, weed seeds exit the harvester off the sieves in the chaff fraction whilst straw is chopped and spread with no loss of harvest efficiency. Weed seeds are exposed to the same rotting effects as in chaff lining but there half the material given the split across the two wheel tracks.

Dust generated when summer spraying is minimised due to the presence of the chaff on the tramlines. Conversely the weed seeds are exposed to a level of disturbance on tramlines which increases their potential to germinate as opposed to continually rotting. This contrasts with chaff lining where the single chaff row is not exposed to any wheel traffic and potentially optimises its rotting potential.

Chaff decks systems have opened new opportunities for alternative forms of weed control not previously thought possible. Weed seed collection has been so effective that very dense populations have emerged in defined rows on the tramlines in crop. Due to the nature of permanent control traffic farming tramlines, growers can use a range of alternative chemistry or cultural practices throughout the season and not affect the main crop. For example, in a 12m control traffic farming system only 8% of the paddock is dedicated to wheel traffic therefore weeds in the chaff lines can be targeted using non-chemical options such as microwave, baling or crimping as potential forms of site specific weed control.

Agronomy for chaff rows created by chaff decks and chaff lining is a key issue and growers need to be aware of some issues that need to be managed. These include:

- Sow through the chaff rows with either a disc or tyne, unsown rows become too weedy without any competition, increase sowing rate on these rows if practical;
- Increase herbicide rates on the chaff rows using higher output nozzles for all passes including knockdown, pre-emergent, post emergent and crop topping;
- Graze with sheep where available to help to reduce the bulk of chaff rows
- Monitor for pests such as mice, earwigs, millipedes and slaters which can breed up in chaff rows, especially when sowing canola and consider on-row baiting or insecticide.

Integrated Harrington Seed Destructor (iHSD)

Recognised as the ultimate form of harvest weed seed control tactic, the mill technology conceived by Ray Harrington is now reaching commercial reality for growers. The Integrated Harrington Seed Destructor (iHSD) comprises of two hydraulically driven cage mills that are mounted within the back of the harvester (just below the sieves). The mills can destroy 93-99% of the weed seeds and then spread the material back out on the paddock without any loss of stubble or nutrients. Suitable for fitting onto all class eight, nine and ten harvesters the mill has been tested to destroy 96% of annual ryegrass seeds, 99% of wild oat seeds, 99% of wild radish seeds and 98% of brome grass seeds in the chaff.

Seed Terminator

Developed by Nick Berry and his group in South Australia the Seed Terminator uses a multi stage hammer mill on weed seeds in the chaff fraction. The mill uses a combination of processes to shear, crush, grind and high impact to destroy over 90% of weed seeds. More research is under way to further quantify this weed seed kill. The mill is mechanically driven with three stages of screen to sort material for size and can be operated at dual speeds of 2800 and 2950 RPM.

Conclusion

Growers now have available a diverse range of harvest weed seed control tactic tactics at their disposal depending on their farming system, location and scale. The options are becoming less labour intensive with a shift away from burning of windrows towards chaff lining or mill technology which leave crop residues and nutrients in place. Although intensive croppers have previously been the major adopters of harvest weed seed control tactic, mixed farmers can also benefit through grazing chaff dumps or chaff lines while reducing weed seed banks.

HWSC is part of a broader weed management package that includes improved herbicide management as well as crop competition, diverse rotations, double knocking and crop topping or hay to stop seed set. The implementation of some or all these tactics will ensure growers keep weed seed banks low but more importantly, remain profitable.

Useful resources

Broster J, et al (2015) Harvest weed seed control: ryegrass levels in south-eastern Australia wheat crops. 17th Australian Agronomy Conference. http://agronomyaustraliaproceedings.org/images/sampledata/ASA17ConferenceProceedings2015.pdf

Walsh M, et al (2017) High levels of adoption indicate that harvest weed seed control is now an established weed control practice in Australian cropping. Weed Science Journal of America 31, 341-347.

https://ahri.uwa.edu.au/harvest-weed-seed-control-tools-they-all-work/

https://ahri.uwa.edu.au/chaff-carts-good-for-the-crop-and-the-sheep/

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Investigating the impact of rain-fed cotton on grain production in northern farming systems

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Take home messages

- Long fallow with good ground cover is paramount for preparing to establish a summer crop.
- November has the greatest probability of adequate planting conditions for summer crops in Northern grains regions.
- Chickpeas provided the best crop choice for double cropping in 2017 post the dryland cotton crop at Narrabri, due to high crop gross margins and its greater ability to extract soil moisture compared to wheat.
- Cultivating after dryland cotton crop did reduce cotton volunteers and ratoons by >100 plants/ha, but yield of the following chickpea crop was reduced by 42% in 2017.

Cotton's fit in a dry-land farming system

Rain fed cotton production is an integral part of dryland farming systems in the northern grain regions of NSW, and southern Queensland. New cultivars with greater lint yield potential, high commodity prices and improved moisture management with the uptake of minimum-till farming have resulted in greater areas of farming land purposely kept for growing dryland cotton. As a result, questions are being raised about the sustainability of growers committing to growing a long-season summer crop in an unpredictable rainfall climate, and its impact on their farming system.

Issues for growing cotton in a dryland farming system include: How to sequence back into grain crops? What crop to grow after the cotton crop? Does cultivation of the cotton ratoons impact yield potential, and if so for how long? If cultivation does not occur, what is the impact of ratoon and volunteer cotton control?

Issues such as planting moisture opportunity, gross margins, rainfall efficiency and the impact on crop sequencing are investigated by the GRDC-funded farming systems projects. In collaboration with the Queensland Department of Agriculture and Fisheries (DAF), CSIRO and the NSW Department of Primary Industries (NSW DPI), the farming systems program is focused on developing systems to better use available rainfall to increase productivity and profitability. We present results from 2 sources here that investigate the options for transitioning from a cotton crop back to a grain crop and the legacy impacts on subsequent crops in a dryland farming system.

Summer planting opportunities for dryland cotton

One of the major decisions growers have when sequencing a cotton crop is the probability of receiving ideal planting conditions. APSIM modelling was used to predict the probability for ideal planting conditions (i.e. 30 mm of rain over 3 days and plant available water > 100 mm) for two northern NSW sites (Spring Ridge and Narrabri) (1a) and south east Qld (Pampas)(1b). Simulations outputs were taken from simulations of crop sequences involving a summer crop following either a winter cereal or chickpea in the previous year (i.e. Wheat – chickpea - wheat - long fallow, or wheat - chickpea – long fallow). All simulations assumed no-till, full stubble retention, with optimum fallow weed management.

All three regions follow a similar trend, although Pampas achieves planting probabilities earlier than both Narrabri and Spring Ridge. The probability of planting summer crop at Narrabri is not as strong during the month of October compared to the other two sites. The models indicate that in approximately 25-30% of years there is a probability of meeting these sowing conditions in October, which is the optimum planting month for cotton in northern NSW (Cotton Seed Distributers, 2013). Importantly this shows that at both Breeza and Narrabri there is only a 65% probability of summer planting conditions occurring by the 15th December, meaning growers may miss out on ideal planting in 3 out of 10 years. On the eastern Darling Downs the simulations predict an extra 10% chance with 75% probability of planting before mid-December.

1(a) 1(b)

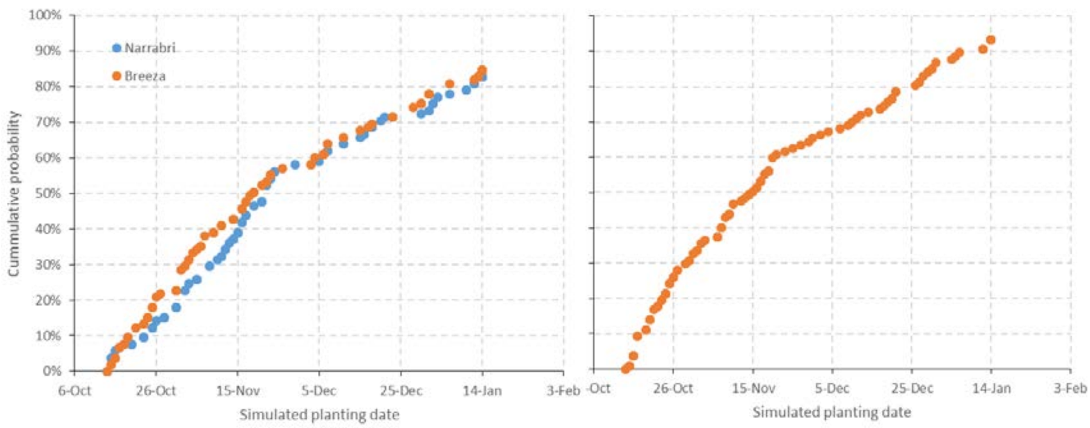

Figure 1. Summer planting opportunity for (a) northern NSW (Narrabri and Breeza) and (b) Pampas, Qld. Where conditions met >30 mm of rain over three days and >100 mm of PAW following a long-fallow after a winter cereal in the previous year (assuming no-till, full stubble retention and optimal fallow weed management).

Post-cotton crop management implications

A grain systems trial was established to evaluate selected farming system options post a cotton crop at the University of Sydney Narrabri research farm "Llara". The study initiated by the NSW DPI northern cropping systems team, investigated various farming management treatments after growing dryland cotton, in particular grain production, soil nutrition, weed control, pathogen levels and system gross margins.

In total six treatments were developed consisting of three crop choices (wheat, chickpeas and a cover crop - barley), and three post cotton cultivation practices (full cultivation, plant line ripping and no till).

The tillage treatments post the cotton crop included:

- No till: No cultivation with following crops sown directly into cotton stubble with a no till planter. Only herbicides were used to control cotton regrowth or volunteers.
- Plant line ripping: Ripping tynes cultivated along the plant line of the cotton crop to a depth of 30cm. No cultivation occurred between the plant lines
- Full cultivation: Offset discs were used twice to ensure full disturbance.

Following a rain fed cotton crop grown in the 2016/17 summer, tillage events occurred approximately 1 month after cotton harvest and subsequent crops were planted on the 26th June with approximately 40% of plant available water capacity (PAWC).

Grain crop yields

After the 2016/17 dryland cotton crop, there was low residual soil moisture in the profile (77 mm of plant available moisture to a depth of 120 cm). The implementation of the cultivation treatments further reduced the plant available water in both the full cultivation and plant line cultivation treatments (Table 1). Along with below average in-crop rainfall during the winter of 2017, these factors combined resulted in low grain yields for both wheat and chickpea. The no till systems resulted in greater grain yield for both crops. The wheat no till treatment yielded 0.28 t/ha higher than the wheat plant line cultivated treatment, while the chickpea no till yielded 0.275 t/ha higher than the chickpea plant line cultivated treatment. This equated to a yield difference of 38% for wheat, and 42% for chickpeas. Crop choice also impacted final grain yield with the wheat no till treatment yielding 34% higher than the chickpea no till treatment (0.97 t/ha and 0.64 t/ha respectively).

Table 1. Plant available water (PAW) after cultivation implementation and subsequent grain yield and crop biomass of wheat or chickpea crops following cotton at Narrabri, NSW (2017)

Site	Crop	Cultivation	Pre crop PAW (mm)	Yield (t/ha)	Crop biomass (t/ha)
Narrabri	Wheat	No till	78	0.97	2.5
Narrabri	Wheat	Plant line cultivation	67	0.70	2.4
Narrabri	Wheat	Full cultivation	56	0.67	2.3
Narrabri	Chickpea	No till	74	0.64	2.1
Narrabri	Chickpea	Plant line cultivation	64	0.37	1.5
Narrabri	Cover crop - barley	No till	79	NA	2.7

Economic returns of crops

An important aspect of the study based at Narrabri was to evaluate the economics of implementing the various management treatments. Due to the low yields, only two treatments were profitable after the 2017 winter harvest – no till chickpeas and no till planted wheat (Figure 2). Although both treatments did receive an extra herbicide than the cultivated treatments, the yield advantage resulted in higher gross margins. While crop choice did impact gross margin, as no till chickpeas resulted in a higher income than the no till wheat ($132/ha and $44/ha respectively). The results show that both cultivation and crop choice had an impact on the gross margin for the grain crop following cotton. For growers considering the value of planting a strategic cover crop after a dryland cotton crop, the farming system's 2017 cover crop (barley) resulted in a cost of $100/ha. The cost includes planting cost, seed purchase and herbicide applications and fallow maintenance up to December 2017.

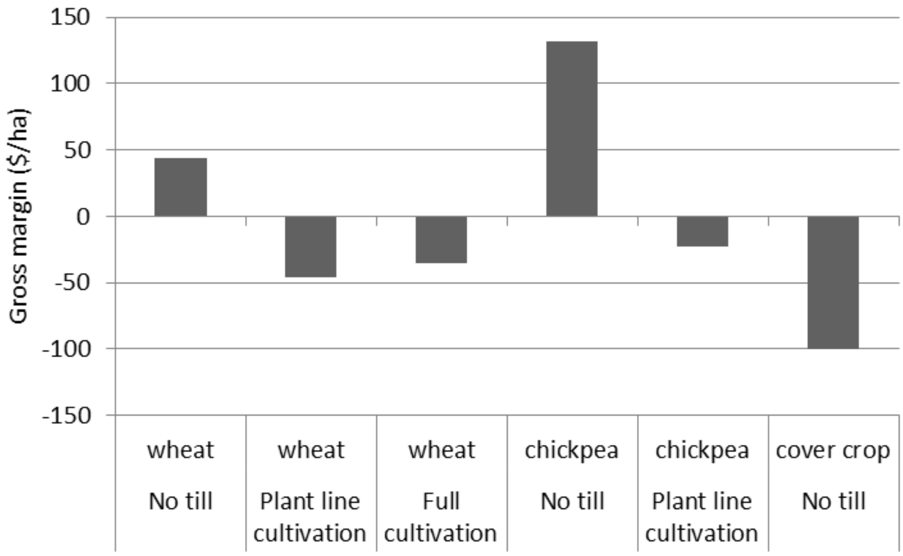

Figure 2. Crop gross margins post a dryland cotton crop from Narrabri, 2017. Grain values used for gross margin analysis are 10 year median prices at port, minus transport costs. Prices used at Narrabri include: wheat - $269/t and chickpea - $504/t

Crop water use efficiency (WUE)

After the 2016-17 rain fed cotton crop, there was 77 mm of plant available water (PAW) at the Narrabri farming systems site (equal to 42% of plant available water capacity (PAWC)). As expected, soil disturbance due to cultivation treatments led to a loss in soil water. The full cultivation reduced plant available water by 21 mm, while the plant line cultivation reduced plant available water by 12 mm. As a result the no till treatments had higher plant available water at planting. Subsequently, the no till chickpeas had the greatest crop water use for all the treatments planted in 2017 (189 mm, $p<0.05$). The impact of cultivation was highlighted by the three wheat treatments, with no till wheat using more moisture than plant line cultivated wheat, which in turn had higher crop water use than the fully cultivated wheat (178, 161 and 144 mm respectively).

While wheat had higher water use efficiency (kg grain/mm crop water use) than chickpea (4.6 and 3.4 respectively), a no till sowing operation resulted in higher water use efficiency than plant line cultivation for both crops (Table 2) ($p<0.001$).

Interestingly crop choice had an impact on the plant available water left in the profile after the 2017 winter crop harvest. There was an average of 57.8 mm plant available water for the wheat no-till and plant line cultivation treatments at harvest, while the chickpea averaged (for the same cultivation treatments) a lower amount of 42.5 mm. This result supports the theory that chickpeas can access more soil water than wheat. They were able to produce grain later in the season, while the wheat treatments were observed to have matured earlier due to moisture stress (Figure 3).

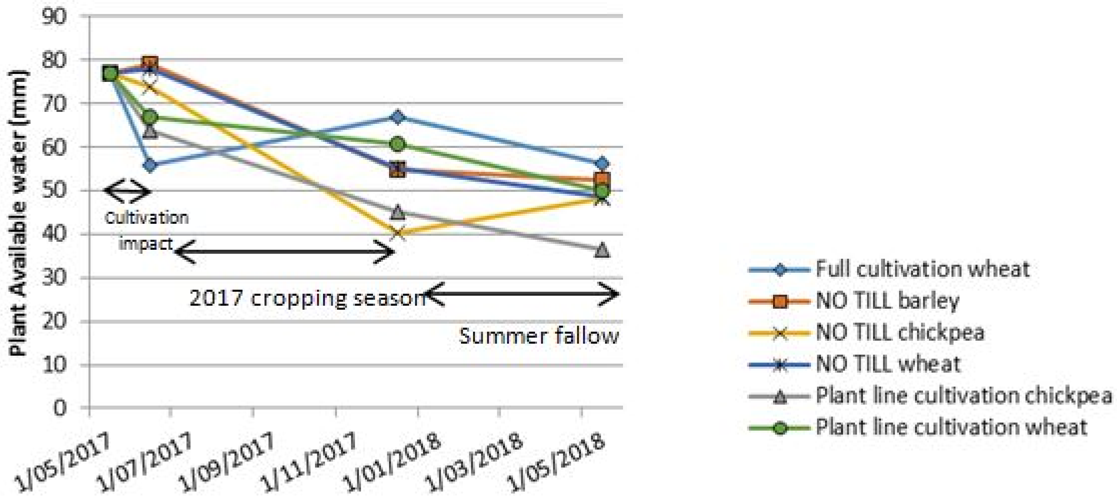

Figure 3. Plant available water, Narrabri 2017-18

Table 2. System water use efficiency, Narrabri 2017

Cultivation treatment	Crop	Crop water use (mm)	Water use efficiency (kg grain/mm/ha)
No till	Cover crop - barley	179	-
No till	Chickpea	189	3.4
No till	Wheat	178	5.5
Plant line cultivation	Chickpea	174	2.1
Plant line cultivation	Wheat	161	4.3
Full cultivation	Wheat	144	4.6
	l.s.d	31	2.4

Cotton regrowth and volunteer control

A major concern for growing rain fed cotton is the number of ratoon and volunteer cotton plants that occur after cotton harvest. Controlling ratoon and volunteers can be expensive and become hosts for pests and diseases. Weeds counts conducted 184 and 300 days after the harvest of the cotton crop show the longevity of the volunteers and ratoon plants. The application of the two cultivation treatments did reduce the number of cotton ratoons and volunteers, with the plant line cultivation having the greatest effect. While both the cultivation activities did incur an extra cost for the management systems, the higher number of ratoons and cotton volunteers resulted in extra herbicide applications for the no-till treatments.

It should be noted that there are no registered or consistently reliable herbicide options available for the control of cotton ratoon.

Table 3. Residual ratoon and volunteer cotton plant numbers (plants/ha) at Narrabri, at 184 and 300 days after cotton harvest

Cultivation	Crop	24/11/2017 184 (DAH)	19/03/2018 300 (DAH)
No till	Wheat	153	90
No till	Chickpea	103	11
No till	Cover crop	156	36
Plant line	Wheat	0	4
Plant line	Chickpea	3	1
Full cultivation	Wheat	26	33
	s.e	80	45

Crop yields following cotton compared to other crop sequences

Farming system trials at Narrabri and Pampas have provided opportunities to compare the yield of crops grown as a double crop after a summer crop, with the yield of crops grown after different previous crops in the cropping sequence. At both Narrabri and Pampas, cotton and sorghum crops were followed by a double crop of wheat. Here the yield of these wheat crops were compared with the yield of wheat crops grown after chickpeas followed by a summer fallow. As shown Table 4, a chickpea- fallow-wheat sequence clearly resulted in a higher yield at both the Pampas and Narrabri trial sites when compared to wheat yields following cotton or sorghum. The yield of the wheat crop following directly after cotton was 65% lower at Narrabri and 47% lower at Pampas compared to following chickpea. It must be noted that both Pampas and Narrabri received below average rainfall during the 2017 winter growing season, but the results show the large impact cotton has on the following crop's yield. At the Pampas site, it should also be noted the impact of a long season summer crop (cotton) compared to a shorter growing summer crop (sorghum). Wheat yield when double-cropped following sorghum yielded significantly higher than following cotton (1.75 and 1.06 t/ha respectively – Pampas 2017).

Table 4. Wheat yield at farming systems research sites Narrabri and Pampas in 2017 following cotton compared to other previous crop sequences.

Site	Previous crop	Crop	Pre-plant PAW (mm)	Wheat crop yield (t/ha)	Wheat crop biomass (t/ha)
Narrabri	Cotton	Wheat	78	0.97	2.5
Narrabri	Chickpea - fallow	Wheat	115	2.20	7.6
Pampas	Cotton	Wheat	146	1.06	3.38
Pampas	Chickpea - fallow	Wheat	188	2.01	6.73
Pampas	Sorghum	Wheat	181	1.75	5.58

The Pampas experiment also compared the impact of different summer crops (maize and cotton) on the pre-plant soil water and yield for subsequent summer crops (sorghum or mungbean) (Table 5). When cotton was the previous crop compared to maize, starting plant available water for the next summer crop was approximately 20 mm lower and yields of sorghum were reduced by 0.4 t/ha and yields of mungbean were reduced by 0.3 t/ha.

Table 5. Comparison of soil water pre-plant and subsequent grain yields of sorghum or mungbean crops following either cotton or maize the previous summer, Pampas 2017.

Previous crop history	Pre-plant PAW (mm) 01/09/2017	Sorghum yield (t/ha)[A]	Mungbean yield (t/ha)[B]
Maize – fallow	145	4.44	1.04
Cotton – fallow	127	4.04	0.73

[A] *cv.* Taurus, sown 3 Nov 17, soil N 150-180 kg/ha, 65 000 plants/ha
[B] cv. Jade, sown 8 Dec 17, 360 000 plants/ha

Conclusion

There are many challenges sequencing cotton in a dry land farming system. Firstly, growers need to evaluate the impact and risk of growing a long season summer crop in a variable climate with unreliable summer rainfall. Northern NSW and south-east Queensland do have high probability of adequate spring – summer planting conditions especially after a long fallow with good ground cover; however, the planting conditions may occur later than the ideal planting date for full lint yield potential.

The opportunity to plant a double crop after cotton in optimum conditions is limited; therefore, if growers do plant, the crop will benefit from capacity to tolerate moisture stress. At Narrabri, chickpeas stood out as the ideal second crop in a double cropping sequence, as they were able to extract a greater amount of soil moisture in a low moisture environment and also resulted in the greatest gross margin. Wheat and the cover crop (barley) did have greater biomass accumulation and did result in greater residual stubble cover, which may have a beneficial impact on future grain crops. While cultivating did have benefits such as reducing the cotton ratoons and volunteer numbers, the cost of the implementation on soil moisture caused significant yield reduction. If growers are able to defoliate their cotton within the regulated date, the ideal treatment is to leave the field in a no till situation. It is noted that there are no registered or reliable options for control of ratoon cotton with herbicides.

We have also found that the greater moisture extraction of cotton compared to other summer crop options can have legacy impacts that last > 12 months, resulting in lower grain yields compared to growing crops after other summer crop options. These negative impacts should be considered when evaluating the profitability of dryland cotton compared to other summer grain crop options (e.g. sorghum, maize).

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Impact of narrow row spacing on grain yield, seed quality and weed competitiveness in sorghum

Trevor Philp, Pacific Seeds

Key words

Sorghum, narrow row spacing, grain yield, seed quality, weed management, competition

Take home message

In a tough season sorghum grown in narrow rows didn't not reduce the yield or increase lodging, narrow row sorghum did reduce weed populations and has potential to increase fallow efficiency.

Introduction

Grain sorghum is currently grown in three main row widths in the north eastern Australian grain belt, 150cm, 100cm and 75cm. Broadly the higher the yield potential and the more reliable the environment the narrower the row spacing.

There has been a renewed interest in narrow rows in field crops due to two main factors

1. Weeds with resistance to one or more herbicide mode of action group.
2. Improving ground cover to drive improvement in the efficiency of subsequent fallows.

Little data is available for Australia on the effect of narrow row spacing in grain sorghum on yield, grain quality, suppression of weeds and improvement in fallow efficiency. There is also no data on narrow row sorghum planted with precision planters.

Summary

In the 2017-18 season nine grain sorghum trials were conducted to measure the effect of row spacing on yield grain quality and weed populations. Six trials compared 50cm, 75cm and 100cm rows, one trial compared 50cm and 100cm rows and two trials compared 50cm, 75cm and 150cm rows.

All configurations were sown at the same plant density using a single hybrid. Only eight trials were harvested, with the trial at Felton abandoned due to lodging. The Felton site was assessed for weed competition and was the only site that had significant weed populations to assess.

No grain quality data is available at this stage.

A significant difference in grain yield was measured at two of the eight sites, one at Tamworth and one at Goondiwindi, no significant difference between the row configurations was measured at any of the other sites.

Row width had a significant effect on weed population at the Felton Site, with weed population reducing with row width.

An across site analysis of the five sites comparing 100cm, 75 cm and 50 cm was conducted. No difference in grain yield was measured between row configurations.

The 2017-18 sorghum season was below average for yield, with grain size also reduced. Most spring planted crops suffered high levels of stress in the grain fill period, due to no rainfall in January.

Trial analysis description

The trait of yield (kg/ha) was analysed in two ways, firstly with row width included as a fixed effect (model 1: Best linear unbiased estimate BLUE) otherwise known as least square mean. This gives an estimate of the mean yield of the each of the treatments.

And secondly with row width included as a random effect (model 2: Best linear unbiased prediction BLUP). The BLUP value is used to estimate/predict the difference between row widths.

Only the BLUPS are reported.

Results

Table 1. Locations, row widths compared and sowing rate by site

Location	State	Row widths compared	Plant density/ha
Clifton	QLD	100, 75, 50 cm	85,000
Felton	QLD	100, 75, 50 cm	75,000
Brookstead	QLD	100, 75, 50 cm	85,000
Pampas	QLD	100, 75, 50 cm	85,000
Yelarbon	QLD	150, 75, 50 cm	65,000
Goondiwindi	QLD	150, 75, 50 cm	65,000
Yallaroi	NSW	100, 75, 50 cm	85,000
Tamworth	NSW	100, 75, 50 cm	75,000
Premer	NSW	100, 50 cm	85,000

Table 2. Individual trial results, grain yield by row width

Location	Row width	BLUP kg/ha	RANK	Rel mean %	se	Rep number	CV%	h2	P.value
Goondiwindi	50CM	3262	1	132.9	58	2	3.37	0.99	0.16
Goondiwindi	75CM	2214	2	90.2	58	2			
Goondiwindi	150CM	1886	3	76.9	58	2			
Premer	50CM	7462	1	100.0	70	3	NA	NA	NA
Premer	100CM	7462	1	100.0	70	3			
Pampas	50CM	3655	1	108.2	263	3	30.22	0.24	0.28
Pampas	75CM	3173	3	94.0	263	3			
Pampas	100CM	3303	2	97.8	260	3			
Brookstead	50CM	3075	1	103.2	186	3	20.01	0.22	0.32
Brookstead	75CM	3039	2	102.0	186	3			
Brookstead	100CM	2828	3	94.9	181	3			
Yelarbon	50CM	1947	2	94.8	177	3	15.52	0.89	0.19
Yelarbon	75CM	1626	3	79.2	177	3			
Yelarbon	150CM	2588	1	126.0	177	3			
Tamworth	50CM	6469	3	97.0	52	2	1.12	0.95	0.18
Tamworth	75CM	6770	2	101.5	42	3			
Tamworth	100CM	6771	1	101.5	42	3			
Yallaroi	50CM	4480	1	101.8	139	3	9.39	0.15	0.34
Yallaroi	75CM	4321	3	98.2	149	2			
Yallaroi	100CM	4396	2	99.9	144	2			
Clifton	50CM	2972	3	100.0	26	2	0.23	0.03	0.04
Clifton	75CM	2972	1	100.0	26	4			
Clifton	100CM	2972	2	100.0	26	3			

Table 3. Across site result, Clifton, Pampas, Brookstead, Yallaroi, Tamworth, and Premer

Treatment	est_blup	rank_blup	rel_blup	se_blup
100CM	4627	1	100	0
75CM	4627	1	100	0
50CM	4627	1	100	0

Table 4. Weed population by row spacing at harvest, Felton Site 2018

Row width	Subscript	Weed count blup	Rank blup	Rel %	se_blup		
100CM	a	49.8	1	175.6	3.2	CV%	19.861
75CM	b	23.5	2	82.8	3.2	h2	0.974
50CM	b	11.8	3	41.6	3.2	P.value	0.166

Discussion

Overall these trials demonstrated no consistent significant difference in yield by row width, although only one hybrid was tested at a single planting rate.

Two sites showed significant difference in row spacing, Goondiwindi showed a clear advantage in the 50cm rows against the commercial standard row spacing of 150cm. This advantage was created due to less lodging in the 50cm, the 50cm rows appeared to create more biomass early and ran into stress earlier than the 150cm rows. The earlier stress resulted in less yield potential, and reduced height, no rainfall occurred in the grain fill period which resulted in the higher yield potential treatment to lodge.

The Tamworth trial had a similar environment but stressed earlier and then was relieved by late rain, which favoured the 100cm rows over the 75 and 50cm rows.

In all sites row canopy closure occurred much earlier in the 50cm row configuration, providing better ground cover. Water use and water use rate wasn't measured in these trials, but the 50cm rows may use soil water at a faster rate in the vegetative phase and potentially increase the chance of stress prior to flowering.

The combination of an appropriate hybrid and plant density and the 50cm row spacing has the potential to improve the sorghum crops competition against weeds, reducing weed seed set and improving yields. This system has potential to improve the fallow efficiency of the overall system, as well as lifting the sorghum yield and reliability in most seasons.

Further work to assess the impact on yield and quality is needed and work is needed to assess the effect on the fallow efficiency after the sorghum crop. Detailed economic analysis is needed to determine the cost benefit of purchasing a narrow row precision planter.

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Tactical sorghum agronomy for the central west NSW and key decision points affecting success

Loretta Serafin, Mark Hellyer, Andrew Bishop and Annie Warren, NSW Department of Primary Industries, Tamworth

Key words

Sorghum, starting soil water, risk, row configuration, desiccation, agronomy

GRDC code

DAN00195 Tactical sorghum and maize agronomy for the northern region – NSW component

DAN00150 Sorghum in the western zone

Take home messages

- Set a target yield based on soil moisture availability, seasonal outlook for rain and local yield expectations.
- Sorghum has a wide sowing window in most areas. Avoid sowing too early (cold) or too late (ergot and frost). Monitor rising soil temperatures to target the optimum time to sow. Aim to avoid flowering during the extreme heat of late December to early January.
- Match the plant population and row spacing to the target yield. Plant uniformity is important so where possible sow using a precision planter.
- Select at least 2 high yielding hybrids that have the desired characteristics (e.g. maturity, standability) for your growing conditions to spread production risk.
- Use registered knockdown herbicides to desiccate crops when they reach physiological maturity to hasten crop dry down, improve harvesting and commence the refilling of the soil moisture profile in dryland crops.

Introduction

Grain sorghum production in central west NSW is not a new phenomenon. In fact, 20 years ago it was recorded in the 2000-2001 ABS Statistics that 60 growers were growing close to 8,000 hectares of grain sorghum with an average yield of 2.6 t/ha.

The success of growing sorghum is largely founded on principles similar to other broad acre crops; the better your management practices, paddock preparation and in-crop rainfall are the higher the chance of economic yields and the lower the risk of poor crop performance or even failure.

Grain sorghum is a deep rooted perennial crop which is the backbone of many northern crop rotations and for good reasons. It is drought tolerant (to a point!), generally reliable, easy to manage and has several markets as grain marketing options. Sorghum is also a useful tool to vary herbicide groups to manage weeds, utilise variable summer rainfall and split labour, cash flow and peak logistical requirements in farm operations.

Starting soil water

Starting soil water is important to most crops, but the level of starting soil water available to sorghum is a strong indicator of likely crop yields especially without much in-crop rain. It has long been recommended to only sow sorghum when 100 cm of wet soil was available to plant into. This recommendation is based on minimising the risk of crop failure, as sorghum is subjected to high temperatures, high evaporation rates and more variable rainfall events during its growth cycle than winter crops.

Choosing to sow sorghum on a soil profile which is less than full, indicates two things; i) willingness to accept a higher risk of crop failure or poor yields (e.g. <2.0t/ha) OR ii) high expectations of above average in-crop rainfall.

The interaction between starting soil water, in-crop rainfall and resulting grain yield was compared at a range of trial sites in north west NSW (**Error! Reference source not found.**). At two of the sites, highlighted in figure 1; when starting plant available water (PAW) was low (<50 mm) but substantial well timed in-crop rain occurred, high yields resulted. In contrast, when starting plant available water was at a moderate level of ~100 mm and very little in-crop rainfall was received a crop failure resulted. This demonstrates that high starting soil water levels can reduce the risk of crop failure but not totally eliminate it.

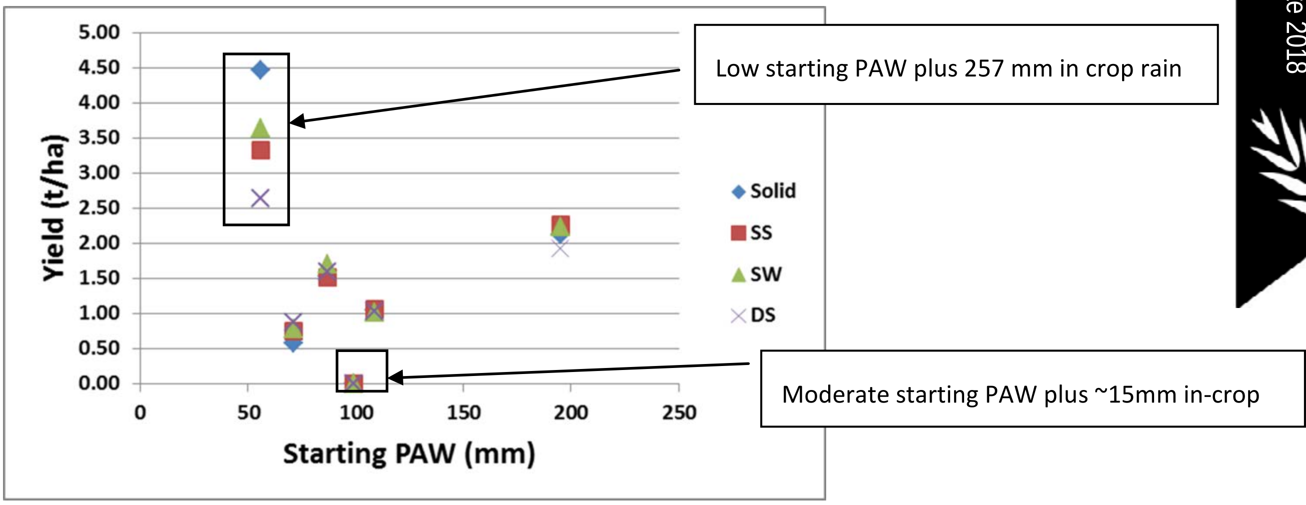

Figure 1. Starting soil water and resulting grain yield from a selection of sites in northwest NSW

When is the best time to sow?

Traditionally, it has been said that sorghum should be planted when the soil temperature at 8 am AESDT at the intended seed depth (about 3–5 cm) is at least 16°C (preferably 18°C) for three to four consecutive days and the risk of frosts has passed. This is a very reliable method which should continue to be followed.

Recently in a GRDC and NSW DPI project there has been research experimenting with moving the sowing window forward by planting into cooler soils. While this practice could significantly widen the sowing window, it is also still currently a high risk option until further evaluation of a range of hybrids and environments is completed. The aim of this work is to be able to move the flowering and grain fill window away from the peak heat conditions in December and January.

In 2017-18 sowing at temperatures below 12°C halved the established plant populations when compared to sowing at the recommended soil temperatures of 16-18°C (Table). In addition the time taken to reach full emergence was up to 6 weeks following the sowing date. This exposes the seedlings to a higher risk of disease and insect attack but also did not always move the flowering window earlier in order to avoid heat stress at flowering and grain fill.

Table 1. Actual plant establishment at three sites in northern NSW under varying times of sowing

Site/ Sowing time	Super early (early August)	Early (late August)	Standard (late Sept/Oct)
Target: 50,000 plants/ha	**Plants/ha**		
Gurley, east of Moree	16,000	28,000	44,000
Mallawa, west of Moree	19,000	25,000	41,000
Breeza, Liverpool Plains	32,000	33,000	50,000

In contrast sowing late i.e. into January exposes the seeds to very high soil temperatures but milder grain filling conditions. It is a balance though to sow crops early enough to ensure flowering and seed filling occur prior to the onset of frosts. There is also a higher risk of ergot and slow grain dry down potentially requiring additional grain drying costs when sowing late.

Selecting a row spacing/ configuration and a plant population

Sorghum can be successfully sown on row spacing's as close as 25 cm or as wide as a double skip on 100 cm configurations depending on the environment, starting water and likelihood of in-crop rain. However, the most common row spacing with yield expectations > 4 t/ha is 75 cm using a precision planter. Due to the tillering ability of sorghum, it will respond to neighbouring competition and environmental conditions to produce more or less tillers.

It is recommended to match your row spacing to your expected yield and your likely availability of soil water. As a rule of thumb, > 4t/ha use row spacing of less than or equal to 75 cm, for yields between 3-4 t/ha use 100 cm row spacing's and for < 3t/ha using 100 cm or skip/wide row configurations. The advantage of wide or skip row spacing is the ability to conserve water in skip areas for flowering and grain fill as the plant roots don't generally explore this area fully before flowering.

As a guide, aim to establish 50,000 plants/ha which still provides plenty of top end yield potential with most hybrids, (exceptionally low tillering hybrids might require higher populations) with potential for yields greater than 10 t/ha.

The use of precision planters enables less seed to be used, more uniform seed spacing to be achieved and as a result more even crop maturity and reduced seed costs.

Hybrid selection

There are a range of sorghum hybrids available on the market from seven different breeding companies. It is recommended to select at least 2 hybrids which have slightly different maturities to ensure flowering times are staged over a couple of weeks to reduce the risk of heat impacting on pollen viability and seed set. Ensuring the crop is not under undue moisture stress during the flowering and grain fill periods will also help to offset the impacts of excessive heat.

Desiccation

Sorghum will be "killed" by frosts at the end of the growing season if left late enough, however, it will re-grow the following spring if not desiccated. Desiccation is an invaluable tool for speeding up crop dry down and evenness of grain moisture, starting the fallow weed control process and stopping the use of soil water which could be preserved for the following crop.

Identification of the correct time to desiccate is crucial to ensuring maximum yield is achieved and additional water use is minimised. Check the lowest grains on the heads for the presence of a "black layer" which indicates the crop is at physiological maturity i.e. has stopped filling grain and is simply drying down and so a chemical desiccant can be applied.

The alternative to desiccation is to leave the crop to naturally dry down and then harvest once the grain moisture content is below 13.5%. This option is typically taken by growers with livestock who would like to utilise the remaining green feed but will mean the crop is standing in the paddock for longer.

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Yield performance of dryland mungbean and soybean — Trangie irrigation experiments, 2016/17 and 2017/18

Leigh Jenkins, NSW DPI

Key words

mungbean, soybean, dryland, yield, summer cropping

GRDC code

DAN00171

Take home messages

- Yield potential of mungbean in a dryland cropping situation ranged from 0.5 to 1.0 t/ha when planted on a full soil moisture profile on a grey vertosol soil in two seasons of experiments at Trangie ARC.
- Mungbean has a short growing season (90–120 days) and therefore requires greater agronomic consideration of the impact of sowing date, insect pest management and disease on yield potential.
- Yield potential of soybean in a dryland cropping situation ranged from 0.2 to 0.3 t/ha when planted on a full soil moisture profile on a grey vertosol soil in two seasons of experiments at Trangie ARC.
- Based on these results soybean is not recommended as a dryland summer crop option in the Macquarie valley.

Background

NSW DPI, with support from the GRDC funded Northern Pulse Agronomy Initiative (NPAI) project, has conducted mungbean and soybean management experiments at Trangie over the past five years. The first three years of experiments (2013/14–2015/16) evaluated agronomic interactions including variety, sowing date, plant density and row spacing combinations. These experiments were conducted under full irrigation.

The NPAI project was extended for a further two seasons (2016/17–2017/18) to evaluate water use efficiency (WUE) and yield components by manipulating biomass and irrigation treatments. In essence, this comprised of three irrigation treatments super-imposed over previous agronomic treatments. For both mungbean and soybean experiments, the three treatments included nil, partial and full irrigation scheduling at pre-determined growth stages and adjusted to suit each crop type.

The purpose of this paper (within the context of the Narromine Grains Research Update, to evaluate dryland summer cropping options for central west NSW) is to report yield data for the equivalent of dryland mungbean and soybean in the Macquarie valley over the past two seasons.

Methodology

All four irrigation experiments reported here were sown into a grey vertosol soil at NSW DPI's Trangie Agricultural Research Centre (Trangie ARC) in central west NSW. The site for each experiment was pre-irrigated prior to sowing to ensure that all treatments started on an equal basis with a full profile of soil moisture. Irrigation treatments were then applied in-crop after establishment. The 2016/17 experiments were flood-irrigated (irrigation treatments located in separate bays of the same field). The 2017/18 experiments were planted on raised beds and watered by siphons, with blank un-watered beds enabling separation of irrigation treatments.

Trial design was a factorial design replicated four times. Agronomic treatments for both mungbean and soybean experiments were the same in both seasons and will be referenced only where applicable in the results. Slight variations in irrigation treatments reflected the conditions for each season and are summarised in Table 1.

Table 1. Irrigation treatment details for 2016/17 and 2017/18 mungbean and soybean experiments at Trangie ARC.

	2016/17 mungbean	**2017/18 mungbean**	**2016/17 soybean**	**2017/18 soybean**
pre-plant irrigation (date applied)	1.5 ML/ha (3 Nov 2016)	2.0 ML/ha (14 Nov 2017)	1.5 ML/ha (3 Nov 2016)	2.0 ML/ha (14 Nov 2017)
sowing date	29 Nov 2016	13 Dec 2017	24 Nov 2016	30 Nov 2017
in-crop rainfall (sowing to final harvest date)	203 mm	131 mm	203 mm	131 mm
1. NIL irrigation	**"PP+0"** Pre-plant + in-crop rainfall only	**"PP+0"** Pre-plant + in-crop rainfall only	**"PP+0"** Pre-plant + in-crop rainfall only	**"PP+0"** Pre-plant + in-crop rainfall only
2. PARTIAL irrigation	**"PP+1"** Pre-plant + one irrigation at first bud/flower only	**"PP+1"** Pre-plant + one irrigation at first bud/flower only	**"PP+2"** Pre-plant + two irrigations at start of flowering & start of seed development	**"PP+2"** Pre-plant + two irrigations at start of flowering & start of seed development
3. FULL irrigation	**"PP+2"** Pre-plant + two irrigations at first bud/flower & mid-flower/first pod	**"PP+2"** Pre-plant + two irrigations at first bud/flower & mid-flower/first pod	**"PP+9"** Pre-plant + full irrigation regime of 9 in-crop irrigations scheduled on crop demand	**"PP+6"** Pre-plant + full irrigation regime of 6 in-crop irrigations scheduled on crop demand
Harvest dates	PP+0: 1 Mar 2017 (92 DAS) PP+1: 4 Apr 2017 (126 DAS) PP+2: 2 May 2017 (154 DAS)	PP+0: 23 Mar 2018 (100 DAS) PP+1: 28 Mar 2018 (105 DAS) PP+2: 28 Mar 2018 (105 DAS)	PP+0: 3 May 2017 (159 DAS) PP+2: 11 May 2017 (168 DAS) PP+9: 17 May 2017 (173 DAS)	PP+0: 4 Apr 2018 (125 DAS) PP+2: 4 Apr 2018 (125 DAS) PP+6: 7 May 2018 (158 DAS)
Total available moisture at each harvest date (RF & irrigation)	PP+0: 275 mm/ha PP+1: 398 mm/ha PP+2: 451 mm/ha	PP+0: 323 mm/ha PP+1: 478 mm/ha PP+2: 628 mm/ha	PP+0: 351 mm/ha PP+2: 451 mm/ha PP+9: 803 mm/ha	PP+0: 328 mm/ha PP+2: 628 mm/ha PP+6: 1231 mm/ha

Soil tests were conducted for gravimetric analysis (starting and finishing soil moistures) and neutron probes were used in-crop, to assess differences in WUE for selected irrigation and agronomy treatments (data not included). Biomass cuts were taken at flowering (to determine peak biomass) and maturity (to calculate Harvest Index) (data not included). The experiments were managed according to best management practice, however it should be noted that pest pressure was minimal for both the 2016/17 and 2017/18 seasons and very few insecticides were applied in-crop. Plots were harvested by plot header and assessed for yield, seed size and moisture content. Only yield results are presented here; quality data for the 2016/17 season has been completed whilst 2017/18 grain samples are still being processed at time of publication.

Results: mungbean irrigation trials

Grain yield results for all treatments in the 2016/17 and 2017/18 experiments are presented in Figures 1 and 2 below. A single variety of mungbean (Jade_AU⁽ᴾ⁾) was used in both seasons. Each experiment had the same 24 treatments comprising of 3 irrigation treatments x 4 plant density treatments x 2 row spacing treatments. The raised bed configuration in 2017/18 meant that slightly different row spacing treatments were used in the second year. Results are discussed in terms of the impact of various treatments with particular reference to the NIL irrigation in-crop (i.e. dryland equivalent planted into a full profile).

2016/17 season

- In 2016/17 the NIL irrigation treatment had a shorter growing season of 92 days (based on harvest date as number of days after sowing) when compared to both partial (126 days) and full (154 days) irrigation treatments.
- As such the NIL irrigation treatment was grown on 125 mm of in-crop rainfall from sowing to harvest after 1.5 ML/ha pre-sow irrigation (total available moisture 275 mm/ha).
- Mean yield for all 2016/17 mungbean NIL-irrigation sub-treatments combined was 0.42 t/ha.
- There was a slight increase in yield for the wider row spacing (66 cm) of the NIL irrigation treatment; conversely there was a slight increase in yield for the narrower row spacing (33 cm) in the FULL irrigation treatment; row spacing effect is NOT considered statistically significant overall.
- At both 33 cm and 66 cm row spacing sub-treatments within the NIL irrigation treatment, dryland grain yield was similar for the first three plant densities (20, 30, 40 plants/m^2 target density at establishment) but reduced when plant density was increased to 60 plants/m^2.

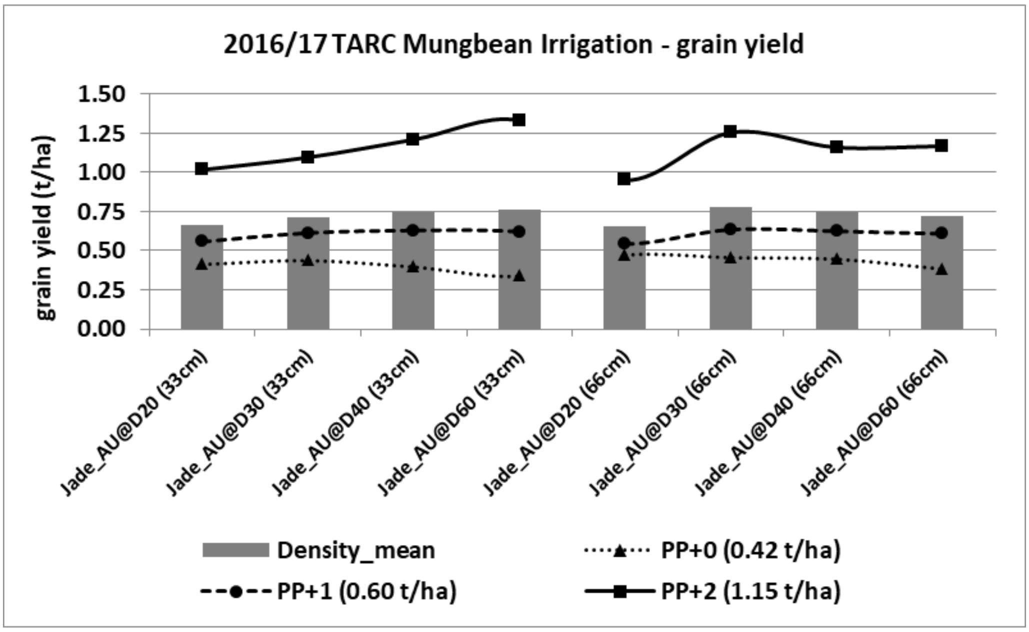

Figure 1. Grain yield response of Jade_AU⁽ᴾ⁾ mungbean sown at four target plant density rates, two row spacing widths and grown under three irrigation treatments at Trangie ARC, 2016/17.

2017/18 season

- In 2017/18 there was very little difference in length of growing season between the three irrigation treatments (100 or 105 DAS) with all treatments reaching physiological maturity at the same time.
- The NIL irrigation treatment was grown on in-crop rainfall of 123 mm from sowing to harvest after 2.0 ML/ha pre-sow irrigation (total available moisture 323 mm/ha).
- Mean yield for all 2017/18 mungbean NIL-irrigation sub-treatments combined was higher than the previous season at 0.97 t/ha.
- There was a slight (not significant) increase in yield for the wider row spacing (50 cm) of the NIL irrigation treatment; however yields were higher at the narrower row spacing (25 cm) in both the PARTIAL and FULL irrigation treatments.
- At both 25 cm and 50 cm row spacing sub-treatments within the NIL irrigation treatment, dryland grain yield was similar for the first three plant densities (20, 30, 40 plants/m^2 target density at establishment) but reduced when plant density was increased to 60 plants/m^2.

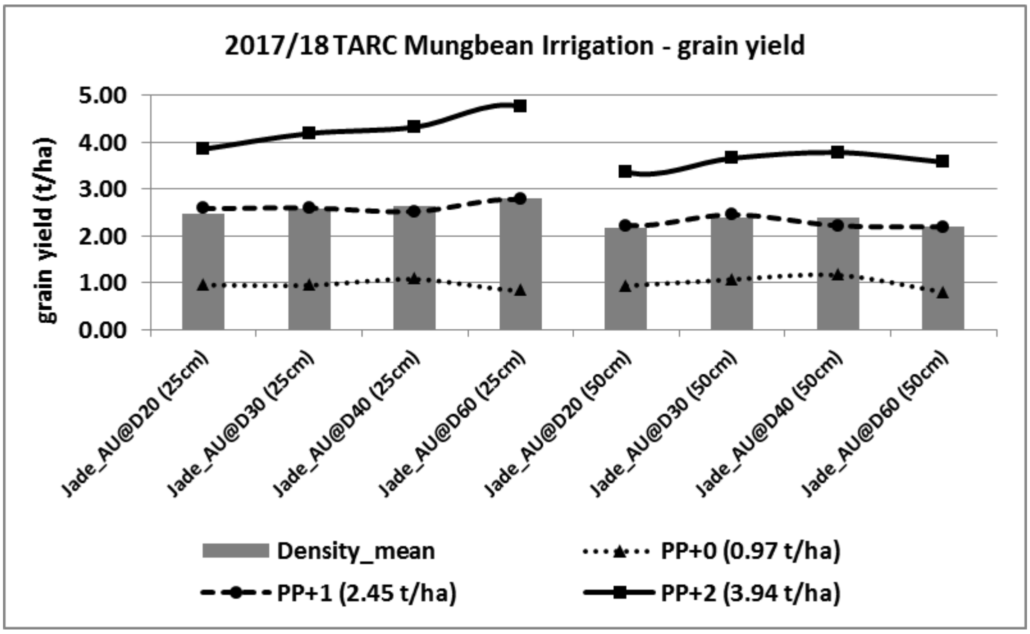

Figure 2. Grain yield response of Jade_AU⟮ mungbean sown at four target plant density rates, two row spacing widths and grown under three irrigation treatments at Trangie ARC, 2017/18.

Results: soybean irrigation trials

Grain yield results for all treatments of the 2016/17 and 2017/18 experiments are presented in Figures 3 and 4 below. Three varieties of soybean (Moonbi⟮, Djakal and breeding line N005A) were used in these experiments. Each experiment had the same 27 treatments comprising of 3 irrigation treatments x 3 varieties x 3 plant density treatments. There was no row spacing treatment in the soybean experiments, with a fixed row spacing of 33 cm in 2016/17 and 35 cm in 2017/18. Results are discussed here in terms of the impact of various treatments with particular reference to the NIL irrigation in-crop (i.e. dryland equivalent).

2016/17 season

- In 2016/17 the NIL irrigation treatment had a slightly shorter growing season of 159 days (based on harvest date as number of days after sowing) when compared to both partial (168 days) and full (173 days) irrigation treatments.

- As such the NIL irrigation treatment was grown on 201 mm of in-crop rainfall from sowing to harvest after 1.5 ML/ha pre-sow irrigation (total available moisture 351 mm/ha).
- Mean yield for all 2016/17 soybean NIL-irrigation sub-treatments combined was 0.28 t/ha.
- Under all three irrigation treatments the same pattern of variety response occurred; Moonbi was the highest yielding, followed by Djakal with the breeding line N005A yielding lowest.
- Within the NIL irrigation treatment, dryland grain yield showed no significant response to changes in plant density (30, 45 and 60 plants/m^2 target density at establishment) for any of the three varieties.

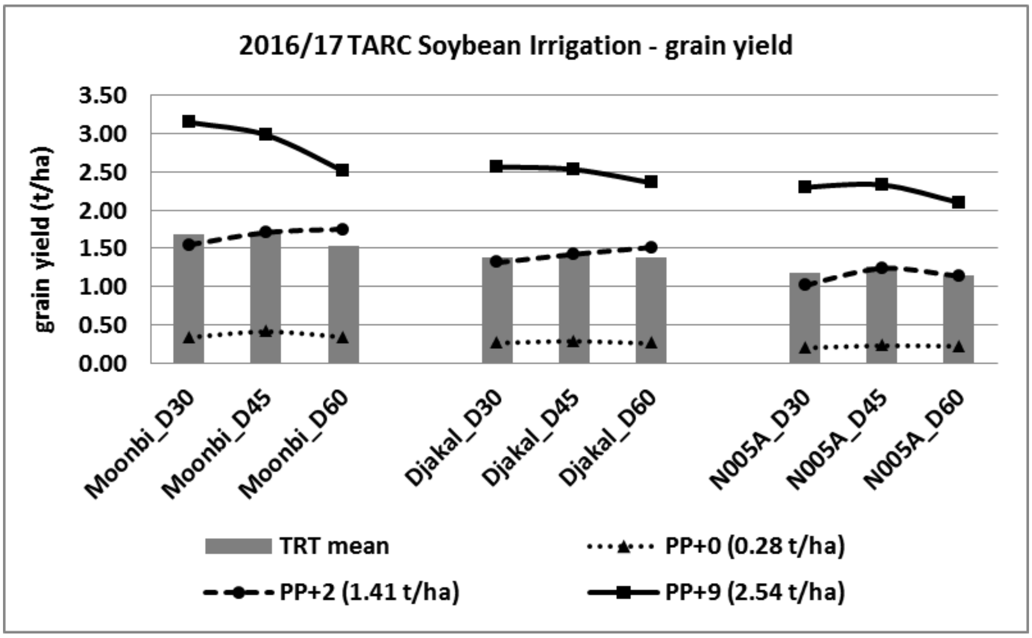

Figure 3. Grain yield response of three soybean varieties sown at three target plant density rates and grown under three irrigation treatments at Trangie ARC, 2016/17.

2017/18 season

- In 2017/18 the NIL irrigation treatment had a much shorter growing season of 125 days (based on harvest date as number of days after sowing) which was the same as the PARTIAL irrigation but over 30 days shorter than the FULL (158 days) irrigation treatment.
- As such, the NIL irrigation treatment was grown on 128 mm of in-crop rainfall from sowing to harvest after 2.0 ML/ha pre-sow irrigation (total available moisture 328 mm/ha).
- Mean yield for all 2017/18 soybean NIL-irrigation sub-treatments combined was 0.19 t/ha.
- There was a variety response to the shorter growing season in 2017/18, Djakal yielded higher than Moonbi under NIL and PARTIAL irrigation treatments; however Moonbi was highest yielding under the FULL irrigation treatment. The breeding line N005A was the lowest yielding variety regardless of irrigation treatment.
- Within the NIL irrigation treatment, dryland grain yield showed no significant response to changes in plant density (30, 45 and 60 plants/m^2 target density at establishment) for any of the three varieties.

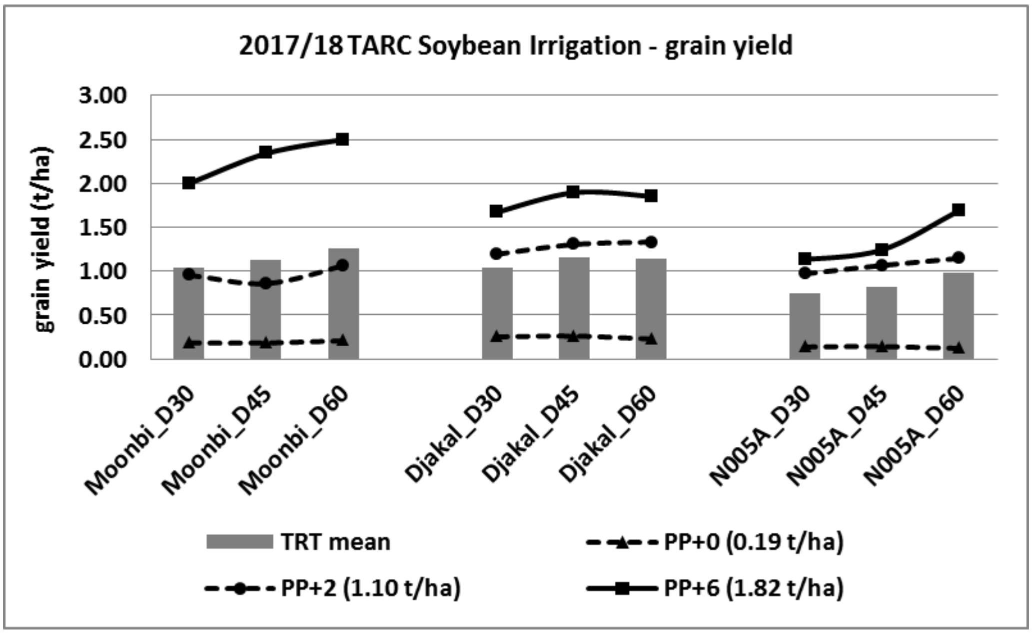

Figure 4. Grain yield response of three soybean varieties sown at three target plant density rates and grown under three irrigation treatments at Trangie ARC, 2017/18.

Discussion

Dryland pulse summer crop options in the Macquarie valley are constrained not only by spring rainfall opportunities (stored soil moisture) but also the amount and timing of rainfall during the summer whilst crops are growing, flowering, setting pods and filling grain. These experiments removed the first constraint by planting on a full profile of stored moisture (pre-sowing irrigation). Despite this there were differences between the two seasons; the 2016/17 season received over 203 mm of in-crop rainfall, whilst the 2017/18 season experienced heatwave conditions in January, February and March 2018, with only infrequent rainfall during that time, resulting in 131mm of in-crop rainfall.

The poor yield response of soybean grown in the equivalent of a dryland cropping situation (i.e. full profile at planting, rain-fed only in-crop) suggests that soybeans are not a profitable option. Maximum yield potential achieved for the NIL irrigation treatment was 0.4 t/ha; average yield potential was less than 0.3 t/ha in 2016/17 and less than 0.2 t/ha in 2017/18. Variety choice would be constrained by predictability of in-crop summer rainfall, with Djakal proving slightly better yielding in short hot growing seasons but Moonbi being the preferred option in longer seasons or partial to fully irrigated (i.e. high rainfall) situations. Previous agronomy research at Trangie ARC has shown that Moonbi must be planted early (before 15 November) to realise full yield potential and enable harvesting before yield and quality are impacted by autumn rainfall in mid-late May.

Mungbean is known to be a much shorter duration crop (usually 90–120 days) which in combination with its indeterminate nature, gives mungbean the ability to respond quickly to in-crop rainfall. This can work for or against the grower depending on the season; it is not unusual to find fully-podded mature plants with a late flush of flowers and the resulting indecision of not knowing when to harvest the crop. Mungbean will also require 90 days of monitoring for various insect pests such as mirids, thrips and heliothis, which can damage flowers and pods very quickly and will require prompt action to control. The final conundrum with mungbean is that the longer the season the more likelihood of pre-harvest powdery mildew developing after early autumn rainfall, which can then result in a lower yield compared to a drier season. Average yield potential of mungbean in the dryland treatment was less than 0.5 t/ha in the 2016/17 season (powdery mildew present) but up to 1.1 t/ha in the 2017/18 season (no powdery mildew). Jade_AU is the preferred variety planted at a target density of no more than 30 plants/m^2. There could be a slight benefit from wider row spacing in some seasons but yield could be reduced in others. Previous agronomy research at Trangie ARC has shown that mungbean should be planted before 15 December; unless the season is very favourable mungbean crops are likely to fail if establishment is attempted during January–February heatwaves.

Summary

Two years of experiments have been conducted at Trangie ARC on a grey vertosol soil, to evaluate mungbean and soybean yield response for a range of agronomic factors in combination with either nil, partial, or full irrigation conditions. The nil irrigation treatment, where the crop was planted on a full soil moisture profile and then received in-crop rainfall only (i.e. no further irrigation) was used to assess the equivalent dryland yield potential for mungbean and soybean crops in the Macquarie valley. From the two seasons of results; mungbean is the preferred dryland summer cropping option, achieving average yields of less than 0.5 t/ha in 2016/17 and less than 1.0 t/ha in 2017/18. Soybean could not be recommended with average yields of less than 0.3 t/ha in 2016/17 and less than 0.2 t/ha in 2017/18.

Further reading

Jenkins, L. (2017) “Evaluation of new mungbean varieties for the Macquarie Valley - Trangie Agricultural Research Centre, 2013 – 2016.” NSW DPI Northern Grains Research Results 2017.

Jenkins, L. (2017) “Evaluation of new soybean varieties for the Macquarie Valley - Trangie Agricultural Research Centre, 2013 – 2016.” NSW DPI Northern Grains Research Results 2017.

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Moore, N., Serafin, L., & Jenkins, L. (2014) “Summer crop production guide 2014.” NSW DPI Management Guide.

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