GRDC Grains Research Update

Grains Research UPDATE

GILGANDRA

Wednesday 20th July 2016

Challenge your management decisions!

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

GRDC Grains Research Update Gilgandra

Wednesday 20th July 2016, Gilgandra Services Club

8:30am registration for a 9:00am start, finish 3:30 pm

Agenda

Time	Topic	Speaker (s)
9:00 AM	Welcome	GRDC
9:10 AM	**Frost** • Increasing temps has NOT reduced frost losses - what are the trends and why? • Variety growth rates and time of sowing decisions • How frosts lie and their impact • Reading the crop - interpreting frost damage and symptoms.	*Jack Christopher (QAAFI)*
9:40 AM	**How much do high stubble loads effect frost risk in pulses?**	*Andrew Verrell (NSW DPI)*
10:00 AM	**New developments in canola harvest management.**	*Maurie Street (GOA) & Leigh Jenkins (NSW DPI)*
10:30 AM	Morning tea	
11:00 AM	**A new strain of wheat leaf rust.** Potential impacts, which varieties and what to look for. **Adult plant resistance** and rust management decision making.	*Robert Park (Uni of Sydney PBI, Cobbitty)*
11:25 AM	**Chickpea and faba bean disease update**.	*Kevin Moore (NSW DPI)*
11:50 AM	**How much can pulse agronomy affect the amount of nitrogen fixed?**	*Nikki Seymour (DAF Qld)*
12:15 PM	**Improving nitrogen use efficiency in cropping systems.** • Understanding loss pathways - how much is lost and factors influencing • The impacts of N source - fertiliser type, organic N and N from pulse crops • Urease and denitrification inhibitors.	*Graeme Schwenke (NSW DPI)*
12:45 PM	Lunch	
1:45 PM	**Super cool results - achieving great results with silo aeration and silo recirculation systems as an aid to fumigation.**	*Philip Burrill (DAF Qld)*
2:15 PM	**Investment in on-farm grain storage and the grain supply chain.**	*Andrew Freeth (Nuffield Scholar 2015, Collie NSW)*
2:40 PM	**Harvest weed seed capture systems in the northern region.** Experience with the Harrington Seed Destructor and the Chaff Deck system for weed tramlining.	*Michael Walsh (University of Sydney)*
3:05 PM	**Fallow management of grass weeds** - button grass and feathertop Rhodes grass.	*Richard Daniel (NGA)*
3:30 PM	Close	

Contents

Compiled by Independent Consultants Australia Network (ICAN) Pty Ltd.
PO Box 718, Hornsby NSW 1630
Ph: (02) 9482 4930, Fx: (02) 9482 4931, E-mail: northernupdates@icanrural.com.au
Follow us on twitter @GRDCUpdateNorth or Facebook: http://www.facebook.com/icanrural

Ⓟ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Frost: An analysis of frost impact plus guidelines to reduce frost risk and assess frost damage

Jack Christopher[1], Bangyou Zheng[2], Scott Chapman[2], Andrew Borrel [1], Troy Frederiks[3] and Karine Chenu[1]

[1]University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI)
[2]CSIRO Agriculture Flagship
[3]Queensland Department of Agriculture and Fisheries (DAF QLD)

Key words

Frost, frost risk, post heading frost damage, wheat

GRDC code

UQ00071

Take home message

- Growers need to consider carefully whether earlier sowing is justified in seasons where warmer temperatures are predicted.
- Warmer temperatures may reduce the frequency of frost events but also increase the rate of crop development bringing crops to the susceptible, post heading stages earlier.
- Situation analysis of national frost impact indicates substantial losses in all regions averaging approximately 10% using current best practice.
- In the northern region, there are even greater losses in yield potential due to late sowing.
- These results indicate that continued research into reducing frost risk remains a high priority despite increasing temperatures.
- Variety guides and decision support software are useful for matching cultivars to sowing opportunities.
- Current variety ratings based on floret damage may not provide a useful guide to head and stem frost damage.
- Crops become most susceptible to frost once awns emerge.
- If crop temperature at canopy height drops below -3.5C after awn emergence, crops should be assessed for damage.
- Consider multiple sowing dates and or crops of different phenology to spread risk.

An analysis of frost impact

The first nationwide assessment of the comparative impact of frost in different Australian cropping regions provides important insights into how to manage frost risk in Australian cropping environments (Zheng et al. 2015).

Climate data from 1957-2013 was used to assess the frequency and severity of frost for each region of the Australian cropping belt. Night time minimum temperatures have been observed to increase over much of the Australian cropping region during that period. However, our analysis showed that frost risk and frost impact did not reduce over the whole cropping area during that time. Warmer temperatures accelerate plant development causing crops to develop to the frost-susceptible, heading stages more rapidly. So counter intuitively, planting earlier or even at the conventional date during warmer seasons may sometimes increase frost risk.

Historic climate data from a grid database and for 60 locations representing each of the four major cropping regions of Australia was used to determine the frequency and severity of frost (Figure 1 top). Crop simulation modelling using the Agricultural Production Systems sIMulator program (APSIM) was used to estimate crop yields. Expert knowledge combined with data from frost trials was used to estimate crop losses. Computer simulation allowed prediction of crop losses for all Australian cropping regions using damage information from a limited number of frost trial sites. It also allowed simulation of potential yields using sowing dates optimised for yield in the hypothetical absence of frost risk, something that has not been achieved experimentally.

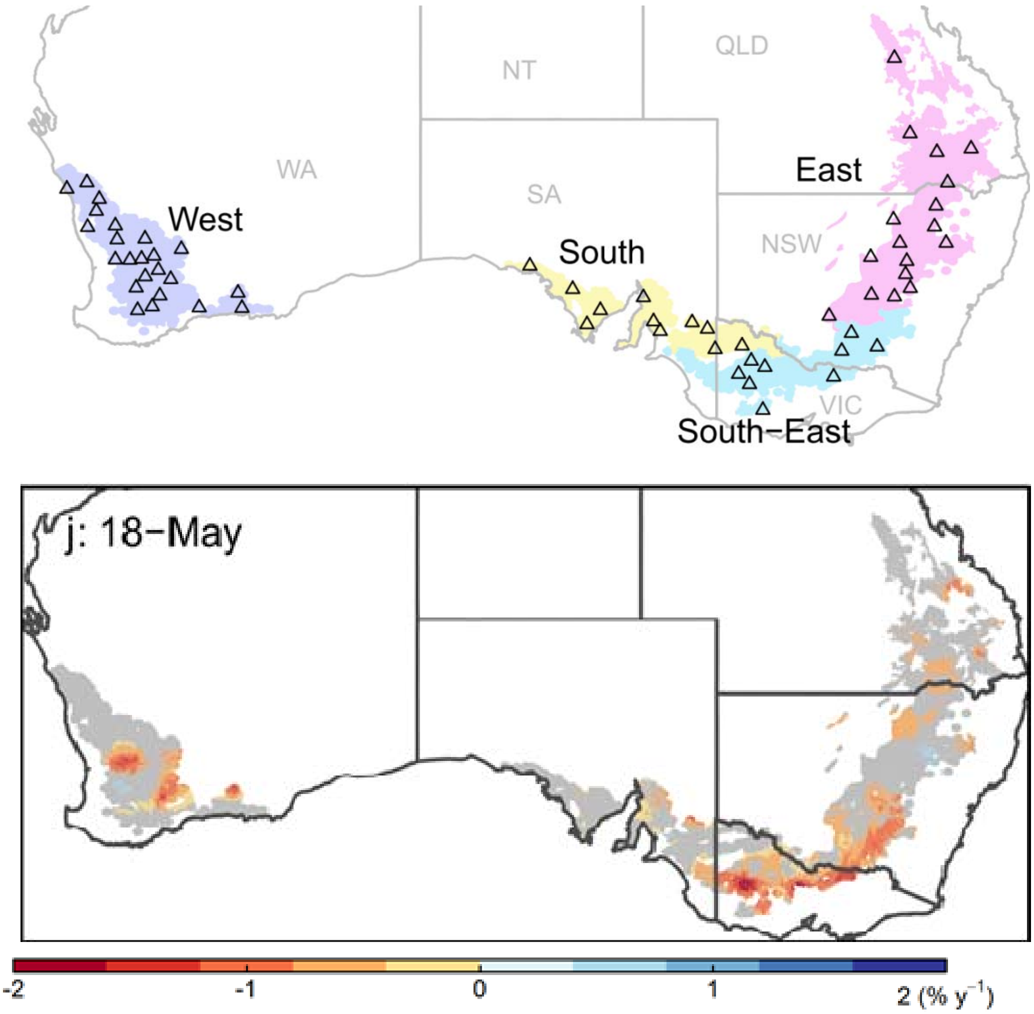


Figure 1. Maps showing sites and regions for which climate data were analysed for the frequency and severity of frosts (top panel) and annual % change in yield loss due to frost from 1957 to 2013; negative values (yellow to red) represent areas where yield loss became worse over recent decades (bottom panel). Estimations in the lower panel were for the cultivar Janz sown May 18th and are based on a ~5 x 5 km grid of climatic data. (Gridded climate data may not reflect local climatic conditions of particular paddocks within each grid as frost events are highly spatially variable.)

The study revealed that estimated yield losses due to direct frost damage averaged close to 10% nationally for all crop maturity types, following current sowing guidelines (Figure 2). To estimate the loss of yield potential due to late sowing, which is necessary in many areas to manage frost risk, a theoretical optimal sowing date (as early as the 1 May) was used. When lost yield potential from delayed sowing (indirect cost of frost) is added to direct damage, estimated yield losses approximately double from 10% to 20% nationally ('direct + indirect' impact in Figure 2). In the eastern grains region (QLD to central NSW), losses were even greater, with estimated yield losses due to direct damage and delayed sowing (indirect losses) of 34, 38 and 23% for early, mid and late flowering cultivars, respectively (Figure 2).

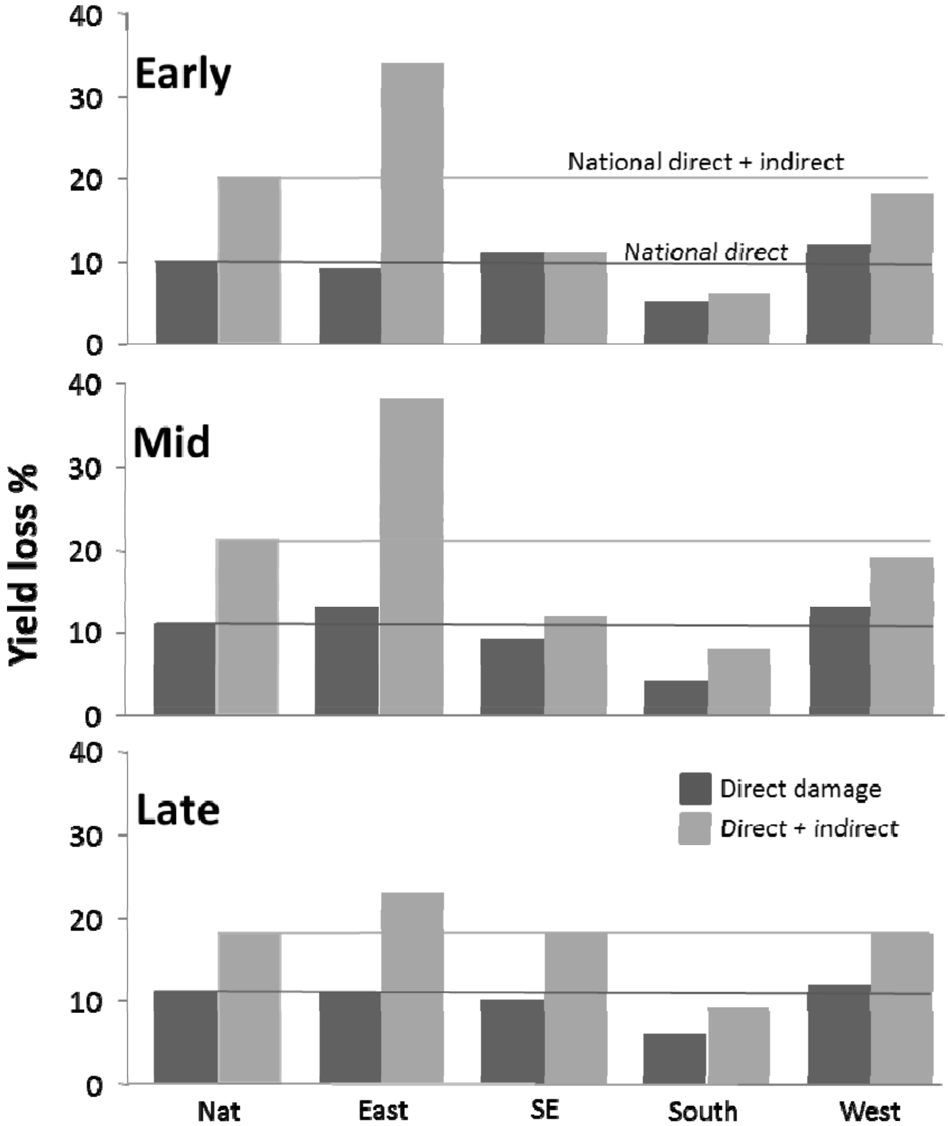


Figure 2. Estimated wheat yield losses (%) due to frost damage for crops sown at the current best sowing date ('direct' frost damage); and crop losses due to both direct damage and delayed sowing currently necessitated to manage frost risks (direct + indirect) for early, mid and late flowering crops.

In some areas in each region, simulated frost impact has significantly increased between 1957 and 2013 (yellow, orange and tan areas, Figure 1, bottom panel). Estimated date of last frost has come later in some areas but earlier in others. However even in areas where the date of the last frost has come significantly earlier, increased temperatures have also increased the rate of development to frost-susceptible heading stages. The modelling suggests that crop heading dates have been brought forward more rapidly than the date of last frost, leading to an overall modelled increase in frost impact in many areas.

These trends over time may have implications for growers making planting decisions. They indicate that sowing early to increase yield potential may not always be the best course of action in warmer seasons, even when a lower frequency of frost events is anticipated. By increasing the rate of crop development, warmer temperatures cause the crop to develop more rapidly to the frost susceptible, heading stages, which may actually increase frost risk.

These results indicate that continued research to reduce frost risk remains a high priority despite increasing temperatures due to climate change. Counterintuitively, percentage yield losses are greatest in the Northern Grain region with the greatest yield losses actually due to delayed sowing rather than frost per se.

Results from this Frost Situation Analysis will provide valuable insights allowing GRDC to better direct research resources. They also provide valuable insights for managing frost risk now.

Guidelines to reduce frost risk and assess frost damage

Matching variety to planting opportunity

The current best strategy to maximise long term crop yields is to aim to time crop heading, flowering and grain filling in the short window of opportunity after the main frost risk period has past and before day time maximum temperatures become too high.

It is essential that varieties are sown within the correct window for the district as outlined in variety guides.

Planting in the optimum window does NOT guarantee that crop loss due to frost will be averted, nor does it always prevent drastic yield reduction due to late season heat and drought stress. However, planting a variety too early can lead to a very high probability of crop loss.

With seasonal temperature variation the days to flowering for each variety will change from season to season as discussed above.

Current variety ratings based on floret damage may not provide a useful guide. Floret damage ratings are yet to be correlated with more significant head and stem damaging frosts.

Measuring crop temperature

In-crop temperature measurements are useful to determine whether a crop may have been exposed to damaging temperatures. A historic comparison of on-farm and district minimum temperatures also allows growers to fine-tune district management recommendations to better suit their particular property and individual paddocks. District recommendations are based on one, or at best a few sites, for each district and may not correlate well with the experience of individual growers. Thus in many instances, the recommendations likely err on the side of caution.

Stevenson screen temperatures measured at Bureau of Meteorology stations do not fully explain frost risk. In crops, the temperature can vary several degrees from the temperature measured in the screen. On nights when still cold air, clear skies, and low humidity conditions combine, temperatures can drop rapidly, resulting in radiant frost (Figure 3). The crop temperatures experienced and recorded can vary widely due to differences in topography (Kelleher et al. 2001), micro-environment (Marcellos and Single 1975) and recording method (Hayman et al. 2007).

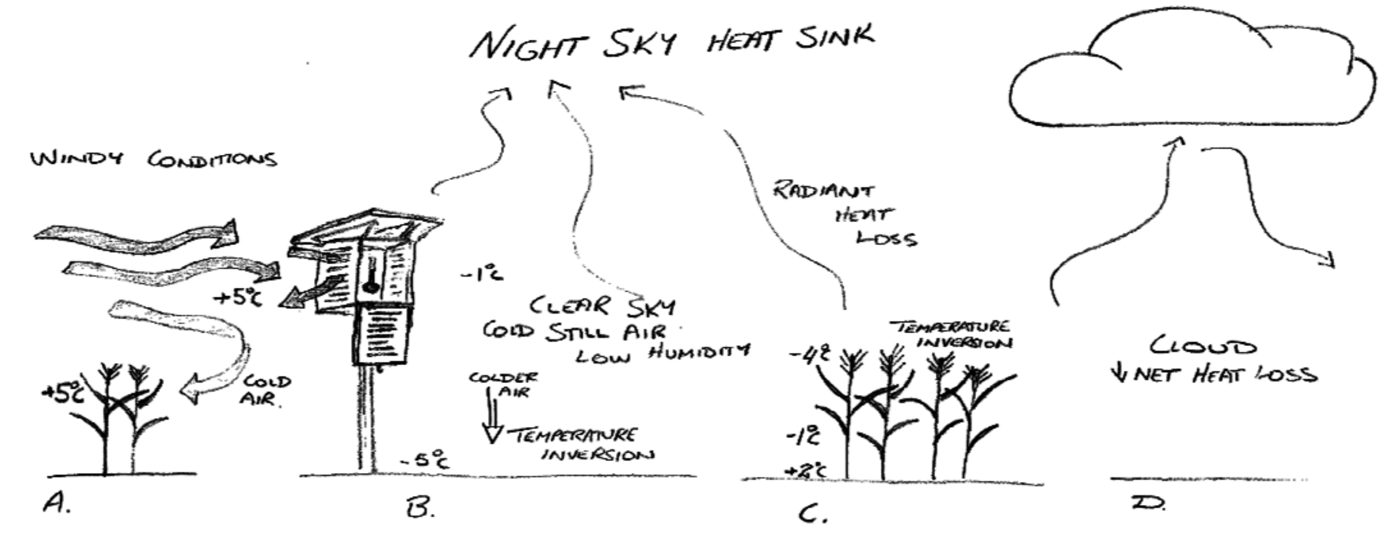


Figure 3. If clear skies and still, cold, low humidity air coincide, heat can be lost rapidly to the night sky resulting in a radiant frost. Minimum air temperatures measured at head height can be several degrees colder than reported "screen" temperatures. Some indicative temperatures are illustrated for (A) windy conditions, (B) clear still conditions in an open area, (C) clear still conditions in a cropping area, and (D) cloudy conditions.

Measurements taken using exposed thermometers at canopy height (Figure 4) give a much more accurate indication of the likelihood of crop damage.

Figure 4. Canopy temperature measured using a calibrated minimum/maximum thermometer. For best results, a minimum of two or three field thermometers are require to give representative temperatures for a crop. In undulating country, more thermometers should be used to record temperatures at various heights in the landscape (Woodruff et al. 1997).

Assessing frost damage

Frost damage varies with crop growth stage. Frost susceptibility generally increases with plant maturity. In particular, wheat and barley become most susceptible after awn emergence (Frederiks et al. 2011ab; 2012).

Young crops

Major economic damage prior to stem elongation is uncommon (Single 1987; Woodruff et al. 1997). Young crops will usually regrow from damage, particularly if good follow-up rain is received

(Afanasiev 1966). Rarely, very severe frosts (lower than −7°C canopy air temperature) may result in damage to the developing crown of the plant (Woodruff et al. 1997).

Advanced crops – not showing ears or awns

In addition to leaf and stem damage booting crops can experience damage to developing ears. This damage usually shows as bleached sections with incomplete ear structures (Figure 5).

Figure 5. Frost damage prior to head emergence.

Advanced crops – ears or awns visible

During and after ear emergence, the plant becomes much more susceptible to frost injury. In wheat, the breaking of the boot is critical for heads to become fully susceptible to frost (Livingston and Swinbank 1950; Single 1964; Afanasev 1966; Paulsen and Heyne 1983). Frost damage after head-emergence often results in severe stem and head damage, and frequently occurs at milder temperatures than damage earlier in development (crop air temperatures ~ −4°C). In elongating stems damage is most easily identified in the 30 mm of stem above the top node. Damaged stem tissue develops a water-soaked dark green colour; later, shrivelling, drying out and bleaching. In severe cases, connection between the head and the rest of the plant may be severed, and the head dies (Afanasiev 1966; Figure 6).

Figure 6. Wheat stem showing severe frost damage. Note the damage around the node, particularly the lower 30mm of peduncle and bleached collar approximately 90mm from the base of the peduncle.

Figure 7. Frosted hollow grain dries back to the typical shrivelled frosted grain.

Frosting of developing grain, after flowering, is difficult to assess. Damaged grain may continue to swell and appear relatively “normal”. However, these damaged grains eventually dry back to shrivelled (potentially) harvestable grains which may cause down grading (Figure 7). To assess this damage, 7 to 14 days after a frost, look for discoloured, shrunken, water soaked or hollow grains that, when squeezed, exude a “straw coloured” transparent rather than “milky” opaque liquid.

References

Afanasev MM (1966), Frost injury in wheat. Plant Disease Reporter 50, 929–930.

Frederiks T, Christopher J, Harvey G, Sutherland, M and Borrell A (2012), Current and emerging screening methods to identify post-head-emergence frost adaptation in wheat and barley. Journal of Experimental Botany 63 (15), 5405-5416.

Frederiks TM, Christopher JT, Fletcher SEH, and Borrell AK (2011a), Post head-emergence frost resistance of barley genotypes in the northern grain region of Australia. Crop and Pasture Science 62, 736-745.

Frederiks TM, Christopher JT, Fletcher SEH, and Borrell AK (2011b), Variation in frost susceptibility of barley (Hordeum vulgare L.) during head-emergence and implications for phenotyping. In Hausman J. -F, Renaut J, Sergeant K and Hoffmann L. (Eds.) ‘9th International Plant Cold Hardiness Seminar’. Luxembourg, 17–22 July. Centre de Recherche Public Gabriel Lippmann.

Hayman P, Alexander B, Knell G and Rebbeck M (2007), The balancing act of managing frost risk. In: Managing frost risk a guide for southern Australian grains. Eds. Rebbeck, M. and Knell, G. pp. 12–19. South Australian Research and Development Institute and Grains Research and Development Corporation.

Kelleher FM, Rollings NM, Poulton DM and Cornish PS (2001), Temperature variation and frost risk in undulating cropland. Proceedings of the 10th Australian Agronomy Conference, Hobart, 29th January – 1st February.

Livingston JE and Swinbank JC (1950), Some factors influencing the injury to winter wheat heads by low temperatures, Agronomy Journal. 42, 153–157.

Marcellos H and Single WV (1975), Temperatures in wheat during radiation frost, Australian Journal of Experimental Agriculture and Animal Husbandry 15, 818–822.

Paulsen G and Heyne E (1983), Grain production of winter wheat after spring freeze injury. Agronomy Journal 75, 705–707.

Single W (1987), Resistance to frost injury during stem elongation and early heading. Proceedings of the ICARDA-INIA symposium, International symposium on improving winter cereals under temperature, drought and salinity stresses, October 26–29, 1987, Cordoba, Spain, 131–141.

Single W (1964), Studies on frost injury to wheat. II. Ice formation within the plant. Australian Journal of Agricultural Research, 15, 869–875.

Woodruff D, Douglas N and French V (1997), Frost damage in winter crops, The State of Queensland Department of Primary Industries, Brisbane.

Woodruff D and Tonks J (1983), Relationship between time of anthesis and grain yield of winter genotypes with differing developmental patterns. Australian Journal of Agricultural Research 34, 1–11.

Zheng B, Chapman S.C., Christopher J.T., Frederiks T., Chenu K (2015) Frost trends and their estimated impact on yield in the Australian wheatbelt. Journal of Experimental Botany 66:3611–3623

Acknowledgements

The research undertaken as part of UQ00071 is made possible by the support of the GRDC. The authors would like to thank them for their continued support.

Contact details

Troy Frederiks
Queensland Department of Agriculture, Fisheries and Forestry
Leslie Research Facility, 13 Holberton St Toowoomba, 4350
Email: troy.frederiks@qld.gov.au
Ph: 07 4639 8876

Jack Christopher
University of Queensland, QAAFI
Leslie Research Facility, 13 Holberton St Toowoomba, 4350
Email: j.christopher@uq.edu.au
Ph: 07 4639 8813

Andrew Borrell
University of Queensland, QAAFI
Hermitage Research Facility, Yangan Rd via. Warwick
Email: a.borrell@uq.edu.au
Ph: 07 4660 3640

Stubble and its impact on temperature in chickpea crops

Andrew Verrell, NSW Department of Primary Industries, Tamworth

Key words

Chickpea, frost, temperature, stubble

GRDC code

DAN00171

Take home messages

- Chickpea sown into flattened residue had lower (av. 1.00C) minimum temperatures compared to standing residue
- Chickpea sown into flattened residue had higher (av. 3.40C) maximum temperatures compared to standing residue
- Stubble thresholds are unknown at this stage

Introduction

Stubble affects soil physical properties such as temperature and moisture. The effect on temperature is due to landscape features such as whether a paddock was on top of a hill, on a hill slope or at the lower end of a slope because cold air (due to its higher density) tends to flow downhill and settle in the lower parts of the landscape, leading to colder pockets where temperatures decline the most.

Stubble cover also affects air and soil temperature. During the day the stubble reflects radiation due to its 'albedo'. A bare, darker soil absorbs more solar radiation than a stubble-covered soil and warms up more readily. The stubble also acts as insulation - it contains a lot of air which is a poor conductor of heat.

Finally, the stubble affects the moisture content of the soil. It takes more heat to warm up moist, stubble covered soil than dry, bare soil. This causes soil temperature of a bare soil to be higher than stubble covered soil during the day (especially in the afternoon). At night, however, the bare soil loses more heat than stubble covered soil due to the lack of insulation (the air-filled mulch being a poorer heat conductor). This is especially noticeable when skies are clear. The air above the bare soil is therefore warmer during the night than the stubble covered surface.

This can affect canopy temperature profiles in crops.

What we did

PBA HatTrick⒫ was sown at 30 plants/m^2 into paired 0.50 m rows with a skip row configuration leaving a gap of 1.0 m between skip rows.

Tiny tag™ temperature sensors were placed in mini Stevenson screens within chickpea experimental plots to measure temporal changes in temperature at ground level. Temperature sensors were placed between 1.0 m wide rows in;

1. plots sown into standing stubble with bare soil between chickpea rows
2. plots sown into flattened stubble with surface stubble between chickpea rows

The sensors recorded temperature every 15 minutes and were left in the plots right thru to harvest in mid-December.

What we found

Chickpeas were sown into 5.84 t/ha of wheat stubble, either standing or flattened.

Standing stubble plots with bare soil between rows:

- had minimum temperatures 1°C warmer at the base of the canopy than surface-stubble plots during vegetative period
- had maximum temperatures -3.4°C cooler at the base of the canopy than surface-stubble plots during flowering and grain fill period
- recorded 5 days with maximum temperatures > 35^{0}C compared to 27 days of maximum temperatures > 35^{0}C where stubble was flattened.

Plant components for the stubble treatments are shown in table 1. Plants sown into bare soil between standing wheat rows had higher grain yields which were achieved thru more pods being set and more seeds being produced per square metre.

Table 1. Effect of stubble treatment on selected plant components.

Stubble	DM/m^2(g)	Grain/m^2 (g)	Seeds/m^2	Pod No/m^2	Seeds/pod	HI
Bare soil	706	270	1072	815	1.3	0.38
Straw	526	226	908	538	1.7	0.43

Conclusions

- Flattened surface residue led to lower minimum temperatures in crop than standing residue
- Flattened residue had higher maximum temperatures during flowering and grain fill than standing residue;
- Flattening and spreading residue can increase crown rot infection in the following wheat crop
- Keep wheat stubble standing in defined rows and sow chickpeas between wheat rows

Acknowledgements

The research undertaken as part of project DAN00171 is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC. The authors would like to thank them for their continued support. Thanks to Mat Grinter and Michael Nowland for their technical assistance in the trial program.

Contact details

Dr Andrew Verrell
NSW Department of Primary Industries
Ph: 0429 422 150
Email: andrew.verrell@dpi.nsw.gov.au

New developments in canola harvest management

Maurie Street, Grain Orana Alliance & Leigh Jenkins, NSW DPI

Contact details

Maurie Street
Grain Orana Alliance
PO Box 2880
Dubbo NSW 2830
Mb: 0400 066 201
Email: maurie.street@grainorana.com.au

Leigh Jenkins
NSW DPI
Mob: 0419 277 480
Email: leigh.jenkins@dpi.nsw.gov.au

"To windrow or not to windrow in 2016?" This is the question, "but if so, when?"

Maurie Street, Grain Orana Alliance

Key words

Canola, windrowing, windrow, swathe, timing, direct head, shattering, yield loss, harvesting loss, desiccation, Pod Ceal™

GRDC code

GOA 00001

Take home message

- Windrowing timing within an acceptable window had no impact on oil % in canola
- Windrowing timing can have a significant positive impact on yield and profitability of canola
- Yield increases up to 0.5t/ha have been seen over relatively short delays in windrowing of only 8 days
- Yield loss to shattering with later windrowing has not shown to be as bad as first thought, particularly in contrast to negative yield impacts for going too early
- Windrowing timing has a limited effect on oil potential in canola
- Direct heading is a viable option to harvest canola and in many cases could maximise profitability
- An economic benefit of over $200/ha can be gained from choosing the best method and timing of canola harvesting

Background

Local focus group meetings of winter 2009 highlighted an interest in validating current recommendations for ideal windrowing times in canola, particularly in the Central West of NSW. One common understanding of the impact of timing was that windrowing too early may reduce oil contents and windrowing later may reduce yield through excessive pod shelling and shattering. Fear of the more tangible and costly loss in pod shattering had seen many paddocks being windrowed much earlier than recommended.

Grain Orana Alliance (GOA) has run multiple trials in 2009, 2010 and 2011 to examine the impact of windrowing timing on oil, yields and profitability as well as the alternate option of direct heading. One of the first trials undertaken at Coonamble in 2009 also investigated the impact on yield and oil when the crop was direct headed using pre harvest treatments with Pod Ceal™ and desiccation with Reglone™.

Methods

All trial sites were large scale replicated trials applied to commercial, farmer sown, paddocks of canola. All windrowing and harvesting was carried out by commercial windrowers (25-40ft swathe) and headers (25-40ft).

This methodology was chosen as it best explores the impact on yield in a full-scale context. Potential for pod shattering during the windrowing operation is a key influence over final yield and could not be duplicated in small scale trial work.

Pod shattering was quantitatively assessed at a number of the sites through catch trays. The methods used were not sufficiently accurate; therefore these details are not included in this report. It should be noted though that any yield loss through shattering is accounted for by a reduction of the final harvested yield. It is harvested yield that drives profitability regardless of shattering at any level.

Windrow timings are described as % colour change (CC), this refers to the percentage of seeds that have started to change colour in the **middle third of the main stem** of the canola plant. To determine this, 30 pods were sampled from the treatment areas, shelled out and visually assessed for colour change. This was completed three times for each replicate/plot. Once the level of CC was established the relevant treatment area was windrowed.

All windrow timings and direct headed treatments were harvested at the same time when all treatments were considered to be ripe enough to harvest. Yields of the whole treatment area were measured with mobile weigh bins with the exception of Nyngan which was weighed over a weighbridge. Grain qualities were assessed by commercial service providers using standard testing procedures.

Yields and grain qualities were analysed using ANOVA at a 95% confidence level and any references to differences can be assumed to be statistically different unless otherwise stated.

Coonamble 2009

Treatments included windrowing at three timings: 10%, 50% and 70% CC, a Reglone® (Reg) treatment at label recommendations (2.25 L/ha) which was then direct headed, Pod Ceal™ (PC) at label recommendations (1L/ha) which was also direct headed and the final treatment which was direct headed with no other treatments. Sprayed treatments were applied by ground but harvested areas did not include wheel track areas.

Dubbo 2009

Three timings were applied in this trial 10%, 50% and 70% colour change.

Warren (Site 1) 2010

Four timings of windrowing were applied at this site, 5%, 40%, 70% and 95% colour change.

Nyngan 2010

Rain prevented the first timing of windrowing to be completed on time so only two timings at 60% and 90% CC were applied at this site.

Warren (Site 2) 2010

Three timings were applied in this trial, 5%, 60% and 95%.

Nyngan 2011

Three timings were applied at 10%, 50% and 90%.

Warren 2011

This trial compared a single windrowing timing at 85% colour change to direct heading with a draper header front fitted with a finger reel and top auger.

Wongarbon 2011

This trial compared single windrow timing at 95% colour change and direct heading with a conventional "tin front" and a Draper front with a finger reel. A different header was used for the harvesting with a Draper front than was used for the other two treatments. The header used for the windrow and conventional treatments maintained the same separator settings for both treatments.

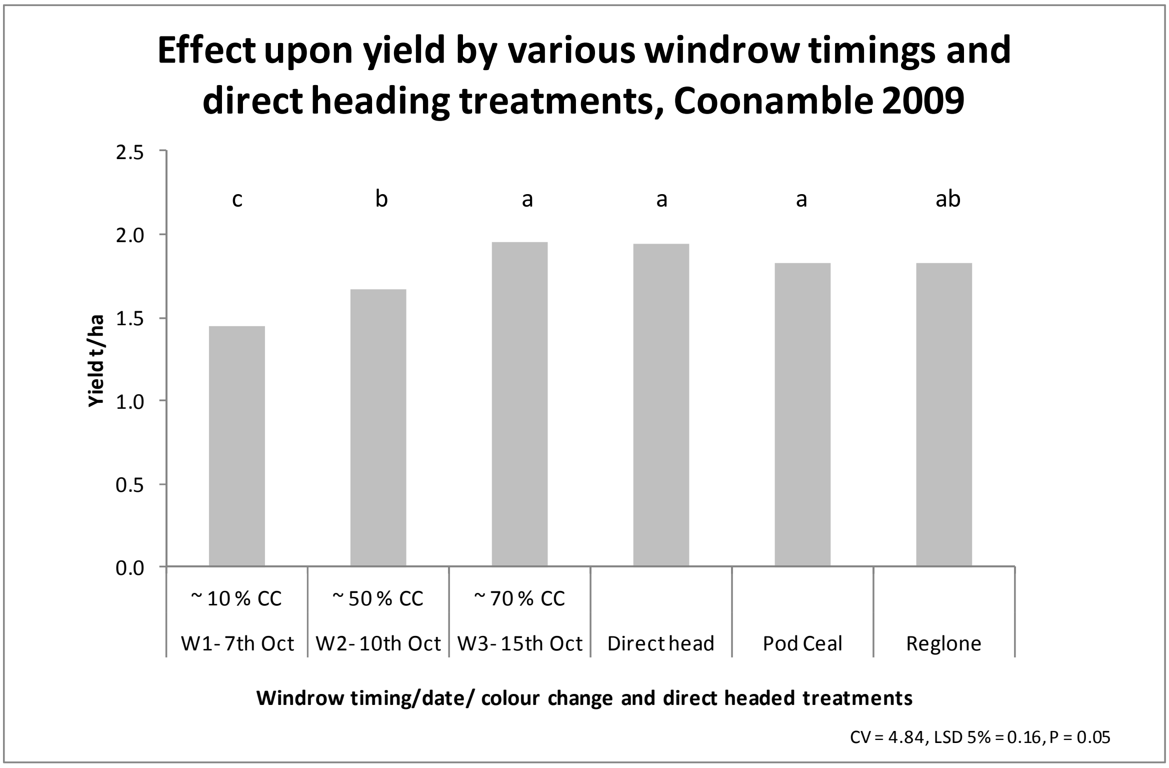
Wellington 2011

This trial compared two windrow timings of 90% CC another timing 6 days later (++100%) and direct heading with a draper front fitted with a finger reel. The same header was used for both harvesting treatments with the same separator settings.

Results

Coonamble 2009

- W1, the earliest timing was the lowest yielding treatment of the three timings
- Each of the three windrow timings are significantly different and yield increased as windrowing was delayed
- The yields between direct headed (no other treatment), Pod Ceal, desiccation with Reglone and W3 were not significantly different and were the highest yielding treatments
- Desiccation with Reglone and W2 were not significantly different
- There was no significant impact upon oil% for any windrow timing or direct heading treatment

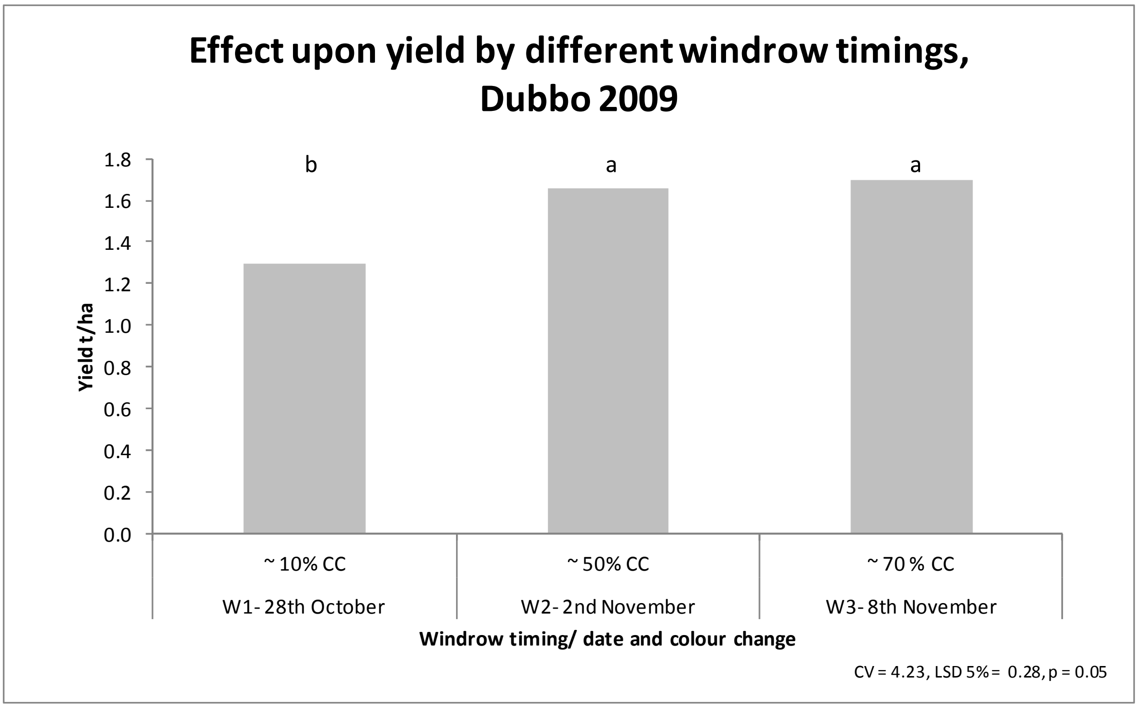


Treatments headed by the same letter denotes no significant difference

Figure 1. Canola yield for direct harvest, PodCeal, Reglone and windrow treatment timings at Coonamble, 2009

Dubbo 2009

- W1 was the lowest yielding treatment
- W3 was the highest yield treatment but was not significantly different to W2
- There was no significant impact on oil% to any timing

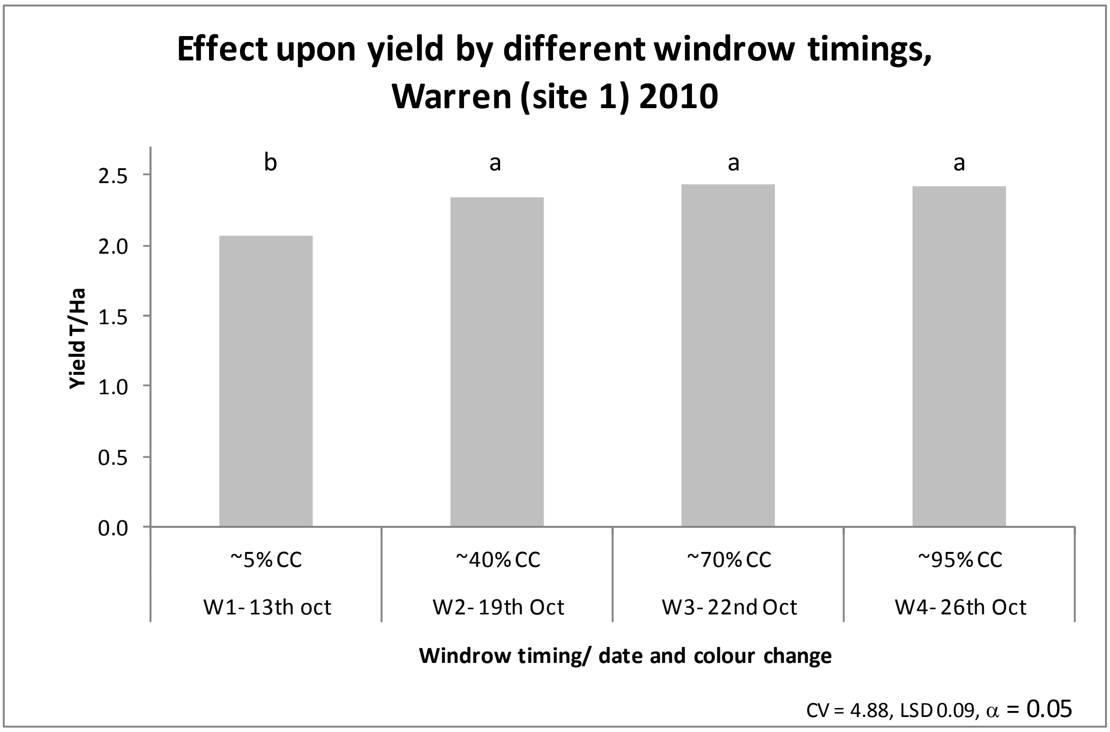


Treatments headed by the same letter denotes no significant difference

Figure 2. Canola yield for the three windrow treatment timings at Dubbo 2009

Warren 2010 (Site 1)

- W1 timing was the lowest yielding treatment
- The other three timing were not significantly different to each other but there was a trend to higher yields with delays past W1 to W3
- Windrowing later than W3, decreased yields but only slightly and not significant
- There was no significant impact on oil% to any treatment



Treatments headed by the same letter denotes no significant difference

Figure 3 . Canola yield for the four windrow treatment timings at Warren 2010

Nyngan 2010- no graph shown

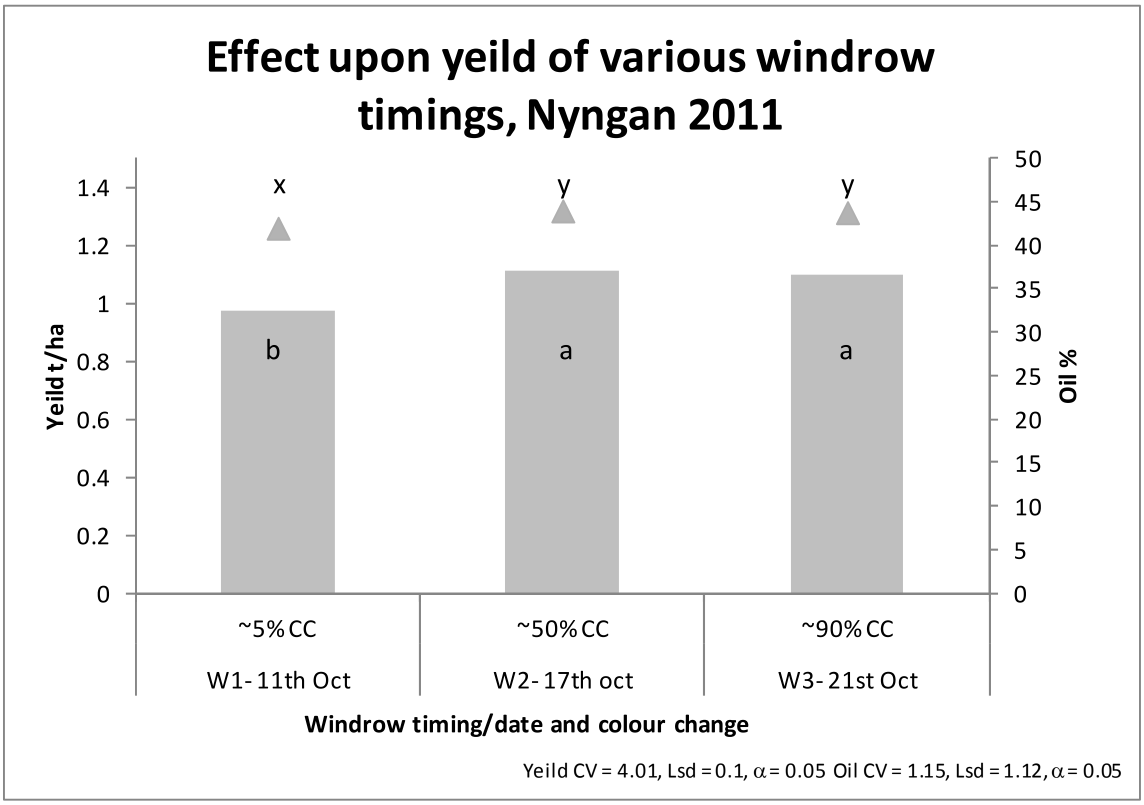
- From a delay in windrow timing from 60% to 90% there was no significant difference in yield or oil%

Warren 2010 (Site 2) - no graph shown

- There was no significant impact on yield or oil at this site

Nyngan 2011

- W1 was the lowest yielding treatment
- W2 and W3 were not significantly different but yielded significantly more than W1
- There was a significant response in oil% with W2 and W3 achieving higher oil than W1



Treatments headed by the same letter denotes no significant difference

Figure 4. Canola yield for the three windrow treatment timings at Nyngan 2011

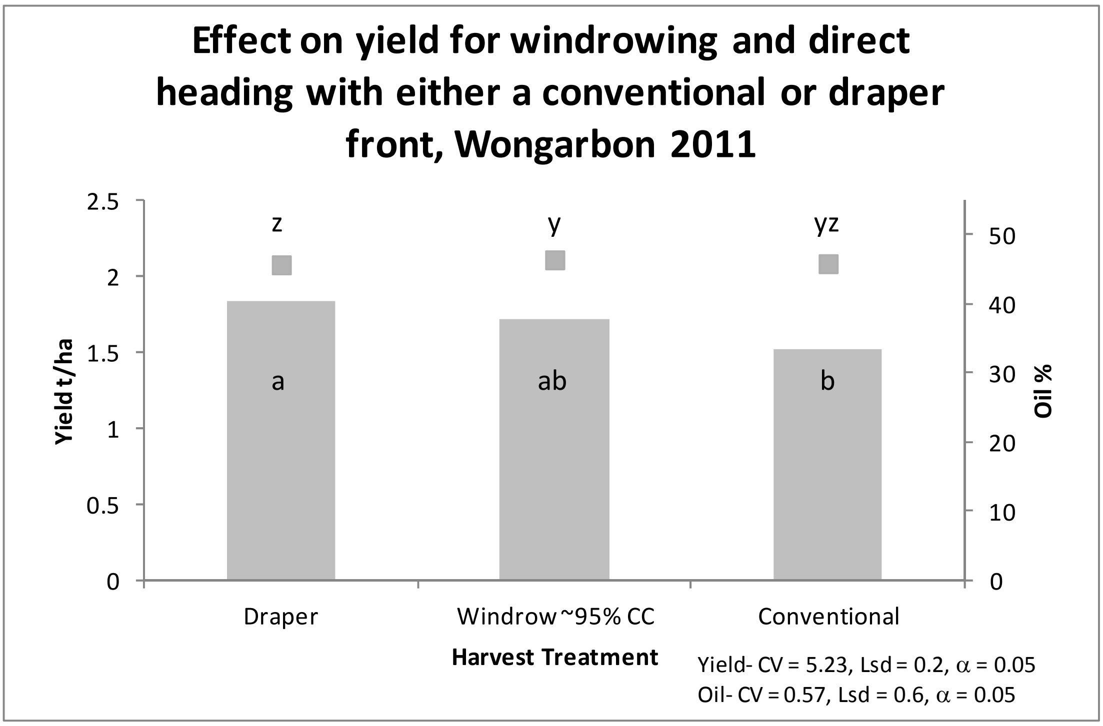
Warren 2011 (no graph)

- There was no significant difference in yield between windrowing at 85% colour change and direct heading
- There was no impact on oil%

Wongarbon 2011

- It should be noted that the trial area experienced a heavy wind storm (>50km/hr) between windrowing and direct heading. This shattered an amount of the standing treatments. The windrows were relatively unaffected
- Two separate headers were used for the two direct heading treatments and it could not be guaranteed their separator configurations were the same
- Neither style of header front was significantly different to the windrow timing of 95% for yield

- The conventional header performed worse than the draper front however it must be noted that there were issues with the reel of the conventional front going too fast for harvesting speed

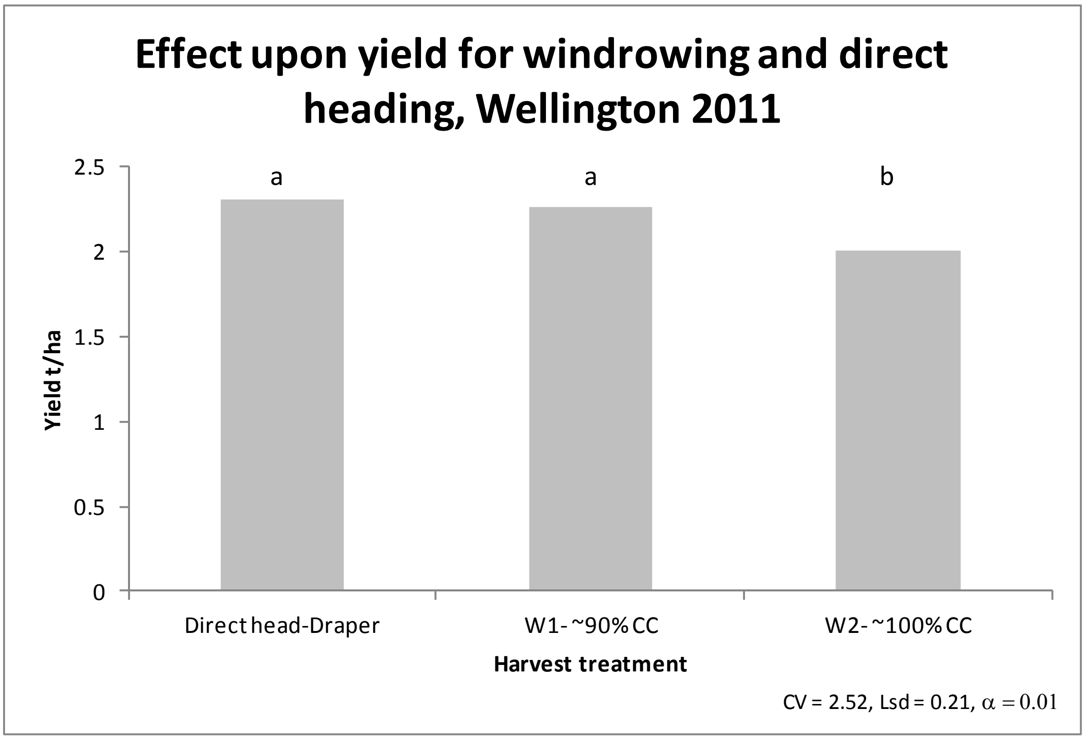


Treatments headed by the same letter denotes no significant difference

Figure 5. Canola yield and oil% as a result of various harvest methods, Wongarbon 2011

Wellington 2011

- Direct heading with a draper front was no different than windrowing at 90%
- Windrowing at the later timing (+100%) yielded ~250 kg/ha lower than W1 at 90% CC or direct heading
- There was no impact on oil% by any treatment



Treatments headed by the same letter denotes no significant difference

Figure 6. Effect on yield of windrowing and direct heading, Wellington 2011

Discussion

Yield

Across the three seasons and a number of sites, early windrowing around 5-10% colour change has consistently resulted in lower yields than later windrow timings. However, windrowing past the currently recommended 40-60% colour change has not always resulted in further significant yield increases. Often there is a trend of increasing yield past the 40-60% colour change timing with trends seen to decline slightly only at 90-95%. Mostly these are not at statistically or commercially significant levels. However, increases in yield have sometimes been quite significant. For example, at Coonamble a ~250 kg/ha yield improvement was realised in a five day delay in windrowing from 50% to 70% CC timing.

This is best explained by considering the process of windrowing whereby the plant's growth has ceased at time of cutting when part of the crop, including seeds, are still green and growing. Once cut, key process within the plant cease and seed will simply start to dry down regardless of their level of maturity and grain weight. This directly prevents any further growth or grain fill of green seeds, those that have not yet reached maturity, and any further yield accumulation that would have occurred otherwise.

Mature seed, when seed will no longer increase in size, is indicated by colour change in the seed and windrow timing is based on only a percentage of the seed within the crop having changed colour. So at the lower end of current recommended timings of 40% CC there is up to 60% of seed that is green, immature and still filling. The earlier the windrow timing, the greater the proportion of seed that will not fill to its maximum potential. Therefore, delaying any action that has the potential to cease grain fill will see the more seeds achieve their maximum size and hence improve yield.

Two recent small plot replicated trials run by Kathi Hertel from NSW DPI supports this theory that seed growth continues up to the point of seed physiological maturity as indicated by colour change. This worked showed that mean 1000 grain weight of the seed on the **main stem** reaches its maximum at 77% CC at the Gilgandra site and 47% CC at the Wellington on the main stem (Hertel, 2012). When seed was sampled at earlier timings than this it had reduced size which would infer reduced crop yields.

This potential maximisation of yield must be weighed against the risks associated with delaying windrowing or delaying to direct head. As the crop passes through the physiological mature stage and starts to dry down, the brittleness of the crop and pods increase. This exposes pods to potential shattering or splitting which would result in yield loss when the crop is either standing before or during windrowing. The ideal windrowing stage therefore should be a balance between maximising the grown yield and not losing this increase in yield through excessive pre windrowing or windrowing losses.

The question that should be asked then is how much of an issue is pod shattering, and when does this start occurring? Current recommendations and industry commentary often suggest that yield will decline through pod shattering, and the risk of this increases substantially as maturity progresses past 60% CC towards 100% CC. However, this has not been demonstrated in our trial work with delayed windrow timing as detailed below;

- Warren in 2010 (site 1) demonstrated no decrease in yields between windrowing at 70% or 95% CC
- Nyngan in 2010, delays from 60% to 90% CC showed no decrease in yields
- Warren 2010 (site 2) showed no decrease yield by delaying from 60% to 95% CC

In addition to this yield data, combinations of both quantitative and visual measurements of shattering at windrowing were made following each windrow timing at most sites. In summary there was no “concerning” level of seed loss observed at any trial or timing, correlating well with the yield data.

However, at Wellington in 2011 due to bad weather, the first of two windrow timings was already late at 90% CC. The second timing which was well in excess of 100% CC was very late and resulted in a decrease in yield of 0.25t/ha or ~11% which was statistically significant. **It must be remembered that this second timing was potentially 7 days later than an already late timing so is an extreme example.**

In summary, yield loss as a result of delayed windrow timing assumedly through shattering has not been demonstrated except in one extreme case with very late timings and colour change in excess of 100%. The belief that significant losses occur when windrowing is delayed past 60% up to ~90% CC is not supported by this data.

When considering the comparisons above also note that if any shattering was to occur it would have been most likely to occur at the late end of the range mentioned i.e. closer to 95% CC. Yields may have actually increased later than the 60% timing before declining, therefore the point of maximum yield could be in some cases above 60% CC. This has been demonstrated at both Coonamble and Gilgandra where measured yield or grain size was maximised at 70% and 77% CC respectively.

Given that windrowing has the potential to reduce yields because it is done before all seed has matured does direct heading have potential to capture higher yields? Four trials have shown that yields from direct headed situations have generally only matched the yields of a **well timed** windrowing (~70-80% CC). If compared to currently recommended windrow timing of 40-60% or earlier as can be seen at Coonamble in 2009, direct heading has outperformed the windrowing.

In the case of two different styles of header fronts being tested (Wongarbon trial site), the results could be best treated as inconclusive. Problems with reel speed on the conventional front and pod shatter due to weather in direct heading treatments pre harvest may have compromised the results. However, despite these two negative impacts neither header front style outperformed the windrowing at 95% CC.

In considering whether to windrow or direct head canola, the Coonamble result further demonstrates an interesting point. This work has shown that windrow timing can a have a significant impact on yield over very short periods. In this situation windrowing five days earlier than optimum yield has been penalised by ~250kg/ha, demonstrating a potentially small window to windrow. The question is if timing delays for a direct headed crop will realise a similar level of impact?

Trial work was undertaken by GOA in 2013 investigating the yield impacts through delayed direct heading of canola. This trial demonstrated the impact of delaying direct heading in canola to have a much smaller consequence than that in windrow timing.

There are a number of new products in the market place promoted to manage potential shattering. If successful they could address one of the key concerns growers have with direct heading of canola. One such product is Pod Ceal which was trialled at the Coonamble site. Pod Ceal aims to minimise pod shatter through a coating applied over the pod. In this trial treatment with Pod Ceal was not statistically different to either direct headed after desiccation with Reglone or direct headed with no other treatment. However, this site in all treatments had minimal shattering problems. If the site experienced conditions supporting greater shattering the advantages of such a product could well be justified. But again, how big is the issue of shattering?

Oil levels

The potential for harvest management of canola through such things as windrow timing or direct heading has shown to have a very limited impact oil %. Very few trials have shown any significant differences in oil % due to windrow timing or direct heading within an acceptable window as discussed above. Of the trials that have resulted in significant differences in oil %, the magnitude has been small often less than 1%.

Oil accumulation in canola starts early after fertilisation but often slows substantially as the seed starts to approach the later stages of development. By the time the crop reaches maturities for windrowing, accumulation has all but ceased.

Relative performance of an individual crop in terms of oil % should not be taken as an indication of ideal windrow timing.

Assessing crop maturity- is there a better way?

Assessing crop maturity to identifying windrow timing is not well understood or consistent with either growers or advisers (Hertel, 2012). There are many conflicting perceptions of what colour change is and what part of the plant to assess as well as simply what is the ideal windrowing timing, the later hopefully clearer after reading this paper.

Currently recommended industry practice assesses crop maturity on the main stem only. It is however worth noting that pods from other parts of the plant contribute to the overall yield potential. Changes in farming practice with reduced sowing rates and established plant populations is resulting in proportionally more grain being carried on podding sites other than the main stem measured in the aforementioned research. One mathematically calculated estimate is that as little as 15% of yield may be carried on the main stem (Yield 2000kg/ha = 200g/m^2 /15 plants/m^2 = 13 g/pl. Main stem seed weight = ~30pods * ~20 seed/pod = 600 seeds * 0.003g/seed = 2gm. Main stem seed weight to whole plant 2g/13g = 0.15).

Given that seed on the secondary and tertiary branches will be less mature than that on the main stem, the maturity for the whole crop would be later than what is estimated by the main stem. That is, current assessment methods have the potential to overestimate the overall crop maturity, but the magnitude of these inaccuracies will vary with plant populations.

Assuming the relationship between colour change in the main stem seed and seed weight detailed by Hertel was transferable to the whole plant; assessing canola maturity based on colour change over the whole plant could be a better estimate of crop maturity? This method would also have the benefit of making allowances for changing plant populations.

This method of assessment would however require further testing and calibration in the field before adoption, but the concept is worth considering.

What is it all worth?

In terms of manipulating windrowing timing to target higher yields it should be remembered that of there is no change in costs but simply a delay in time. Hence any increase in yield is 100% profit. And the improvement in profit can be substantial as demonstrated in figure 7 below with an extra $208/ha increase by delaying windrow timing for only eight days at Coonamble.

Work by Hertel suggested that yield increases through delayed windrowing can be up to $50/ day at their peak.

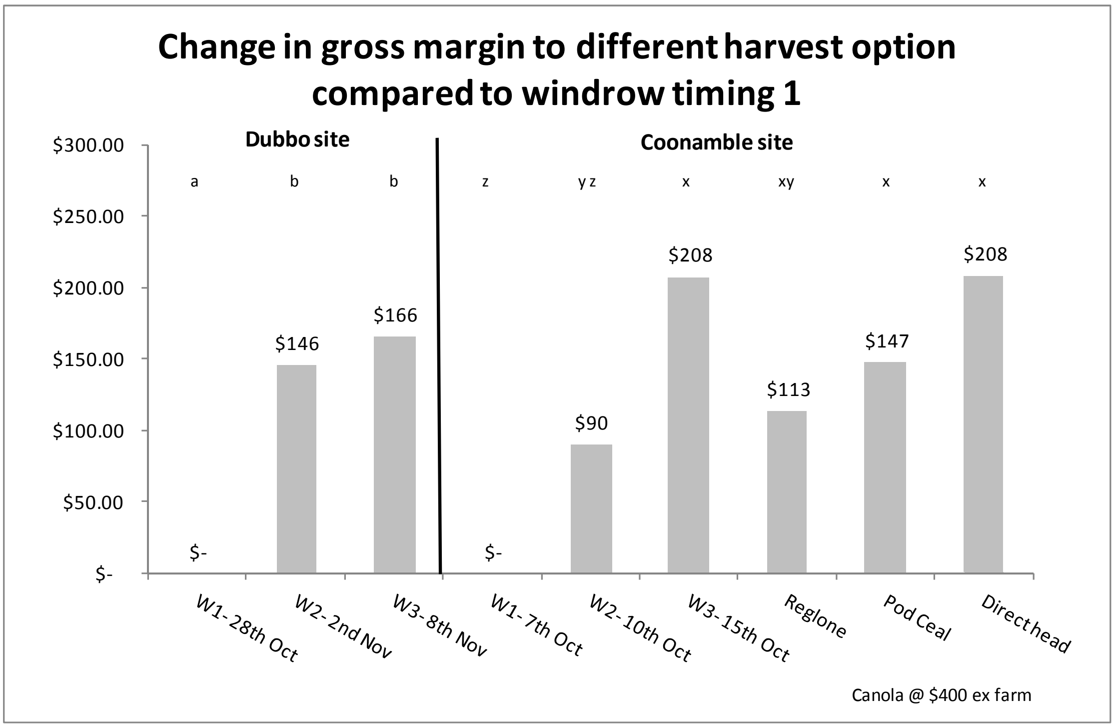
Comparing windrowing to direct heading can be more complicated. There are obvious savings in windrowing costs when direct heading, but the rate of harvesting windrows to direct headed crops can vary. Key considerations may include the width of the windrower swathe compared to that of the header front when direct heading but also the potential shortening of daily harvesting hours in extreme conditions when direct heading. Recently published was a Harvest Module in the Canola Technology Update 2012 which provides a lot of data and information to help compare the two harvesting options for your own circumstance.

This resource can be accessed by clicking on the following link-

http://www.australianoilseeds.com/__data/assets/pdf_file/0016/9142/MODULE_7_-_Harvest_Management_Kathi_Hertel_-_V2_Sep_2012.pdf

However, many comparisons often suggest there is little difference in harvesting costs for direct headed crops and those that are windrowed with maybe slight cost advantages in direct heading. This is demonstrated in the graph below showing similar impacts on gross margins between a well-timed windrowing and direct heading.

The following graph depicts the benefits for the average of all the treatments, taking into account average yields and additional costs as well as oil penalties/bonuses from Dubbo and Coonamble in 2009.



Treatments headed by the same letter denotes no significant yield difference only ($\alpha = 0.05$)

Figure 7. Relative cost / profit difference of different harvest options to W1 at the Dubbo and Coonamble canola harvest trials

Therefore, the choice on harvesting methods may depend more on other positive and negative aspects of each method rather than that of the direct economics. These aspects are covered well in the publication mentioned above. But it is clear that windrow timing can have a substantial impact on profitability of growing canola.

Conclusion

From these trials it could be concluded that windrowing timing has a limited effect on oil% in canola.

Windrowing earlier than the current recommended timings has always resulted in a significant reduction in yields which could seriously challenge profitability of crops in some situations.

The findings from these trials suggest that striving to meet the **upper end** of the current recommended windrow timings is important (40-60% CC) and should be targeted as a **minimum** as significant yield penalties have been demonstrated consistently if cutting earlier than these levels. However, there have been trials such as at Coonamble in 2010 and at Gilgandra in 2011 (Hertel) that have clearly demonstrated that delaying past these times have shown to further improve yields. In all of GOA's trials they have shown trends in yields to have continued to increase up to 90+% CC.

One major concern with such a practice is the risk of shattering before or during windrowing when timings are delayed. These trials have demonstrated no yield penalty from delays in windrowing except in an extreme case. This fact could infer that the magnitude of the shattering is small and statistically insignificant against any potential yield gains over the same period.

In the decision to delay windrowing later than 60% CC, growers and advisors should consider that each season or indeed each paddock could be different. Firstly growers and advisors should consider the crops current growing conditions. If the crop is experiencing terminal moisture stress delays beyond 60% it may not be warranted but if moisture is still available, even if limited, consider the findings of this work-

- Windrowing later than current recommendations may or may not result in increased yields, but in some cases they have

- Windrowing up to 90% colour change has not demonstrated any significant yield decline.

So if there is a potential for improved yields with delaying till later with little downside risk, why not? And remember that direct heading is an option if you cannot get the windrowing done when you need to.

Selection of varieties with greater shattering tolerance through breeding programs, changes in plant populations and farming systems as well as better machinery may mean that pod shatter may not be the issue that it was when the original recommendations of timings were founded. This may have contributed to this drift in an "ideal" timing recommendation which is now over 30 years old.

Direct heading has also shown to be a suitable management option for canola demonstrating that it often matches the performance in terms of yield of a well-timed windrowing, not so compared to ill-timed windrowing.

The choice to direct head canola therefore is better based upon the other pros and cons of such which are well detailed in the GRDC's recently published Direct Heading Fact Sheet that can be accessed at

GRDC Direct Heading Fact Sheet:
http://www.grdc.com.au/~/media/F3089AE19FFC498389DE786683461209.pdf

What these trials do hope to demonstrate is the potential economic benefit gained by getting it right. The availability of windrowers at the correct time or the other advantages offered through windrowing should be considered.

Acknowledgements

Special thanks to:

Clyde Agriculture "Netherway" Coonamble,

Graeme Callaghan- Graeme Callaghan & associates, Dubbo

Garry Evans- "Larry's Plains", Dubbo

Lindsay Northcott, North-Hill harvesting, Young

Syngenta crop protection, Australia

Agspec, Australia (Pod Ceal™ Distributors)

John DeLyall- Pioneer Hi Bred Australia

"Haddon Rig" Warren

A Walker-"Erlside" Warren

R Ledger "Erlside" Warren

The Waas family at Nyngan

The Street family- Wongarbon trial site

Mason Family, "Spicers Run" Wellington

Michael White and Co. Wellington

Julie Monroe- GOA

All windrowers, agronomists and growers that have helped out along the way.

References

Hertel, K A, (2012). Canola technology update. Module 7 Harvest Management V2 September 2012. Australia Oilseed Federation.

Contact details

Maurie Street
Grain Orana Alliance
PO Box 2880
Dubbo NSW 2830
Mb: 0400 066 201
Email: maurie.street@grainorana.com.au

Part I: New pathotypes of wheat leaf rust: potential impacts and what to look for and Part II: Adult plant resistance and rust management decision making

Professor Robert F. Park, Plant Breeding Institute, Cobbitty, The University of Sydney

Key words

Leaf rust, wheat, minimum disease standards, resistance, pathotype

GRDC codes

US00063, US00064, US00067

Take home messages

- Rust pathogens spread freely and rapidly through the Australasian region. While this is predominantly in a west-to east direction, recent years have seen two examples of east-to-west transport.
- Monitor for the presence of the green bridge, and if present, make sure it is destroyed at least 4 weeks before crops are sown, either by heavy grazing or herbicides.
- Warm, moist autumn conditions favour the development of leaf rust.
- Monitor crops of vulnerable varieties for leaf rust in 2016 and send samples for pathotype analysis to the Australian Rust Survey. This service is free to all, and is funded by the grower levy paid to the Grains Research and Development Corporation.
- The identification of rust pathotypes involves greenhouse tests in which seedlings of indicator varieties are infected, and takes about 3 weeks. These tests are increasingly being supplemented with DNA-tests that are much quicker (less than 48 hours). The DNA tests provide useful basic information but are nowhere near powerful enough to identify pathotypes.
- Genetic resistance to rust in cereals delivers significant benefit to Australian grain growers, estimated at $1.1 billion annually with wheat alone, and remains the basis of rust control.
- Minimum disease standards remain important for industry-wide benefit from genetic resistance.

Part I: New pathotypes of wheat leaf rust: potential impacts and what to look for

Australian wheat crops are infected by 3 different rust pathogens: stem rust (caused by *Puccinia graminis* f. sp. *tritici*), stripe rust (caused by *Puccinia striiforimis* f. sp. *tritici*), and leaf rust (caused by *Puccinia triticina*).

What is a rust pathotype?

Many people who have an interest in cereal production would have heard the term “pathotype” (pt., aka “races” or “strains”). Pathotypes are variants within a pathogen that differ in their ability to overcome rust resistance genes in cultivars. A good recent example of this concerns stripe rust and the wheat cultivar Mace. Like many current wheat varieties grown in WA, Mace carries the stripe rust resistance gene *Yr17*, a gene that is expressed at all growth stages (often referred to as seedling resistance genes, major resistance genes, all stage resistance genes; see below). While Mace is resistant to the “WA stripe rust pathotype”, first detected in 2002, the resistance provided by *Yr17* was overcome in eastern Australia by a new pathotype, 134 E16 A+ Yr17+, first detected in 2006. To date, the latter Mace-virulent pathotype has not been detected in WA. For this reason Mace is regarded as susceptible to stripe rust in eastern Australia, and resistant to stripe rust in WA.

Thirteen pathotypes of wheat leaf rust have been detected in north eastern Australia since 2000, of which six have been common in recent years (**Table 1**).

Rust pathotype surveillance

The existence of rust pathotypes was first shown in the early 1900s in the USA. Not long after, Australian annual rust surveys were initiated at the University of Sydney, and continue to this day at the University's Plant Breeding Institute (PBI). The identification of rust pathotypes at the PBI is a free service that is open to anyone who would like to submit a sample for analysis. Directions on how to do so are provided at the end of this paper. Following this procedure is vital if the viability of a rust isolate is to be ensured.

Pathotype identification involves infecting seedlings of a set of cereal varieties, each carrying a different rust resistance gene, with a field collected sample of rust. The ability or inability of the rust isolate to overcome the resistance gene in each variety allows the pathotype or pathotypes present to be identified. These tests take about 3 to 4 weeks to complete, and if a new pathotype is suspected, often a longer time is needed to confirm this. The pathotype identification work at PBI is increasingly being supplemented by DNA profiling, which is comparatively quicker and may only take several days. However, while providing important information and a means by which exotic rust incursions can be recognised rapidly, as yet, DNA profiling is nowhere near powerful enough to identify individual pathotypes.

The long-term studies of pathogenic variability of rust pathogens conducted at PBI have clearly established that Australia and New Zealand comprise a single rust epidemiological unit, within which rusts migrate freely and rapidly. This is why a nationally coordinated approach to the genetic control of cereal rusts (i.e. the Australian Cereal Rust Control Program) is fundamental to success.

The annual surveys of rust variability carried out at PBI have and continue to form the basis of all gene-based rust control efforts. They monitor the effectiveness of rust resistance genes in commercial cultivars; determine the implications of new rust pathotypes in the rust responses of current cereal cultivars; facilitate the discovery and introduction of new resistance genes into locally adapted germplasm; and allow pre-emptive resistance breeding.

Table 1. Current common wheat leaf rust pathotypes detected in north eastern Australia

Pathotype	Year first detected	Comments
104-1,2,3,(6),(7),11	1989	Derived by mutation from pt. 104-2,3,(6),(7),11
104-1,2,3,(6),(7),11 +Lr37	2002	Derived by mutation from pt. 104-1,2,3,(6),(7),11
76-1,3,5,7,9,10,12 +Lr37	2011	Derived by mutation from pt. 76-3,5,7,9,10,12 +Lr37
76-3,5,7,9,10,12,13 +Lr37	2013	Derived by mutation from pt. 76-3,5,7,9,10,12 +Lr37
76-1,3,5,7,9,10,12,13 +Lr37	2014	Derived by mutation from pt. 76-3,5,7,9,10,12,13 +Lr37
104-1,3,4,6,7,8,10,12 +Lr37	2014	Exotic incursion, origin unknown

Recent changes in the wheat leaf rust pathogen in eastern Australia

A new pathotype of the wheat leaf rust pathogen, *Puccinia triticina*, was detected in a sample of leaf rust collected from a crop of the wheat cultivar SQP Revenue at South Bool Lagoon (South Australia) in mid-August 2014. The new pathotype, 104-1,3,4,6,7,8,10,12 +Lr37, was considered to be an exotic incursion based on its unique virulence profile and SSR fingerprint. This pathotype is the 12th documented incursion of an exotic wheat rust pathogen since Australia-wide cereal rust surveys conducted by University of Sydney staff began in 1922.

Following its initial detection in SA, pt. 104-1,3,4,6,7,8,10,12 +Lr37 spread rapidly throughout much of the eastern Australian wheat belt and in late September 2015 it was identified in samples of leaf rusted wheat collected from four separate locations in the northern region of the WA wheat belt.

Pt. 104-1,3,4,6,7,8,10,12 +Lr37 carries virulence for the resistance genes *Lr27*+*Lr31*, and the adult plant resistance (APR) gene *Lr12*, and combines this with virulence for *Lr13* and *Lr37*. All four resistances occur in Australian wheat varieties, and consequently this pathotype has resulted in increased leaf rust susceptibility in some varieties.

Of the 37 varieties for which detailed information is available, the leaf rust responses of 31 are not expected to change (**Table 2**). The remaining six carry resistance genes either singly or in combination that prior to the detection of the new pathotype would have provided some protection against leaf rust. While all of these varieties are now more susceptible to leaf rust, it is very fortunate that all except Mitch and Wallup carry a level of residual resistance due to the presence of uncharacterised APR. Growers of these varieties are nonetheless advised to monitor crops for the presence of leaf rust.

The leaf rust responses of the newer varieties B53, Buchanan, Flanker, Kiora and Mansfield are currently not well known, and further data will be collected during the 2016 cropping cycle.

If any rust is found on any cereal crop, it can be sent to the Australian Rust Survey (see below), where it will be analysed and the sender will be notified of the results. This is a free service, and its success in establishing the distribution and occurrence of known rust pathotypes, and in detecting new rust pathotypes, depends entirely on the collection and submission of samples.

Table 2. Leaf rust response and genotype for wheat varieties grown in north-eastern Australia[a]

Change in response due to new pathotype?	Cultivar	Leaf rust response	Rust resistance genotype	
			All Stage	Adult Plant
No	Adagio	MSS	*Lr37*	Uncharacterised
No	Baxter	S	*Lr17a*	***Lr34***[b]
No	Beckom	S	*Lr3a, Lr37*	***Lr34***
No	Bolac	S	Nil	***Lr34***
No	Cobra	MR	*Lr3a,* ***Lr23***	Uncharacterised
No	Dart	SVS	*Lr1, Lr13*	***Lr34***
No	EGA Gregory	MR	*Lr3a,* ***Lr23***	***Lr34***
No	EGA Wedgetail	MS	Nil	***Lr34***
No	EGA Wylie	MS	*Lr3a, Lr17a*	***Lr34***
No	Elmore CL Plus	RMR	*Lr24*	***Lr34***
No	Forrest	MS	*Lr1, Lr13*	***Lr34***
No	Gauntlet	MS	*Lr3a, Lr37*	***Lr34***
No	Gazelle	MR	*Lr24, Lr37*	Uncharacterised
No	Impala	SVS	*Lr37*	***Lr34***
No	Janz	MRMS	*Lr24*	***Lr34***
No	Lancer	RMR	*Lr24*	***Lr34***
No	Livingston	MSS	*Lr1, Lr13, Lr37*	***Lr34***
No	Manning	MRMS	***Lr23****, Lr26, Lr37*	Uncharacterised
No	Merlin	MS	*Lr1*	Uncharacterised
No	Naparoo	S	*Lr13, Lr24*	Nil
No	Orion	R	*Lr20, Lr37*	Uncharacterised
No	Scenario	MSS	*Lr37*	Uncharacterised
No	Sentinel	R	*Lr26*	***Lr34***
No	SF Ovalo	MSS	*Lr13*	Uncharacterised
No	Spitfire	S	*Lr1*	***Lr46***
No	SQP Revenue	SVS	*Lr13, Lr37+*	Nil
No	Sunguard	MR	*Lr24+*	***Lr34***
No	Sunvale	S	*Lr37*	***Lr34***
No	Sunzell	MS	*Lr1, Lr13, Lr37*	***Lr46***
No	Ventura	MSS	*Lr13, Lr37*	Uncharacterised
No	Viking	MSS	*Lr13*	***Lr34***
Yes	Mitch	SVS	*Lr13, Lr27+Lr31*	Nil
Yes	Sunlamb	MRMS	*Lr37, Lr27+Lr31*	Uncharacterised
Yes	Sunmate	MS	*Lr1, Lr37, Lr27+Lr31*	Uncharacterised
Yes	Suntime	MS	*Lr1, Lr37, Lr27+Lr31?*	Uncharacterised
Yes	Suntop	MRMS	*Lr1, Lr27+Lr31, Lr37*	Uncharacterised
Yes	Wallup	SVS	*Lr13, Lr20, Lr27+ Lr31?*	Nil
?	B53	S	*Lr?*	Nil
?	Buchanan	MR	?	Uncharacterised
?	Flanker	MRMS		***Lr34***
?	Kiora	MRMS		***Lr34, Lr46***
?	Mansfield	MS		Uncharacterised

[a]For full genotypes (i.e. stem rust, stripe rust and leaf rust), see Cereal Rust Report 2016 14(4) [http://sydney.edu.au/agriculture/plant_breeding_institute/cereal_rust/reports_forms.shtml]

[b]Genes in bold font are effective against common pathotypes of the leaf rust pathogen.

Pathotype surveys and rust control

To have maximum impact in disease control, surveys of pathogenic variability in rust pathogens must be closely integrated with the development and management of new wheat cultivars. Where this has been practiced, surveys have provided both information and pathogen isolates that have underpinned rust control efforts, from gene discovery to post-release management of resistance resources. Information generated by pathotype surveys has been used to devise breeding strategies, inform selection of the most relevant isolates for use in screening and breeding, define the distribution of virulence and virulence combinations, allow predictions of the effectiveness/ineffectiveness of resistance genes, and issue advance warning to growers by identifying new pathotypes that overcome the resistance of cultivars before they reach levels likely to cause significant economic damage.

Maintaining and improving current levels of rust control

It has been estimated that 50% of the cost of plant improvement involves breeding to maintain current yield and quality levels to meet the challenges of degrading growing environments and evolving pathotypes of major pathogens (“maintenance breeding”). Protecting the *ca*. $1 billion savings to the Australian wheat industry from resistance breeding and reducing the current impact of rust diseases will only be possible if resistance remains a priority in breeding programs, and if the wheat industry as a whole continues to support genetic approaches to rust control.

Part II: Adult plant resistance and rust management decision making

Many people in the cereals industry would be familiar with the expression that a variety’s disease resistance has ‘broken down’. This expression can be misleading because it suggests that the variety itself has changed in some way. However, the shift in a variety’s response to rust is actually caused by a change in the pathogen that causes the disease. This is why monitoring rust populations for new pathotypes is critical to informing knowledge of how a variety’s resistance stacks up.

The emergence of a new rust pathotype can result in a resistant variety becoming more susceptible to rust. Because this shift is often subtle, describing the change in a variety to a new rust pathotype accurately can be difficult.

Changes in a variety’s response to new pathotypes are influenced by the nature and number of genes that confer resistance to the disease. Such resistance genes protect against the disease either at all growth stages, which is called all stage resistance (ASR; also referred to as ‘seedling’ or ‘major’ resistance), or at adult plant growth stages only, which is called adult plant resistance (APR; also referred to as minor gene resistance).

Genes that confer ASR usually provide very high levels of protection against rust, while those conferring APR usually provide moderate levels of protection. A variety may carry one or both gene types, resulting in different effects on resistance levels.

Where a variety only carries an ASR gene, and this is overcome by a new rust pathotype, its resistance rating may change from highly resistant to highly susceptible.

There are many examples of such changes in a variety’s resistance levels – known as the ‘bust’ part of what is known as the ‘boom and bust cycle’. One of the first examples of this shift was recorded in the Eureka wheat variety’s resistance to stem rust. Eureka was highly resistant to stem rust when it was released in 1938. However, because this variety only has one ASR gene (*Sr6*) to protect it against stem rust, it became highly susceptible to the disease when this single gene was overcome by a new rust pathotype in 1942. Similarly, the stripe rust resistance rating of Mace⸙ was downgraded from highly resistant to very susceptible because it only has one ASR gene (*Yr17*), which was overcome by a new pathotype in eastern Australia. However, in other grain growing regions such as Western Australia, Mace⸙ remains highly resistant to stripe rust because its single ASR gene has not been overcome.

Adding another dimension of complexity are the many wheat varieties that carry a combination of ASR and APR genes. Having both these genes means a pathotypic change can result in a slight increase in susceptibility that occurs when the ASR gene is overcome by a new pathotype, but the APR gene is still effective in providing 'back-up' resistance .

Field testing is the only reliable way to determine the levels of back-up resistance provided by the APR gene. For example, the full impact of the new wheat leaf rust pt. 104-1,3,4,6,7,8,10,12 +Lr37 will not be known until further field tests are completed this year.

While many years of painstaking genetic research has led to a sound understanding of ASR genes, intensive genetic analyses of APR genes began only about 20 years ago. Consequently, information about the APR genes in Australian wheat varieties is incomplete, and varietal information on rust response such as that which appears in the University of Sydney's Cereal Rust Update reports (see: http://sydney.edu.au/agriculture/plant_breeding_institute/cereal_rust/reports_forms.shtml) has partial information only. The rust response and rust genotype (i.e. which rust resistance genes are present) of varieties that are currently grown in north eastern Australia are provided in **Table 2**. Where a variety is rated as having useful resistance (i.e. either: R, MR, MR-MS), and does not carry an effective ASR gene, the resistance present must be due to APR. For example, from **Table 2**:

- Sentinel⸙ carries the ASR gene *Lr26*, which is not effective to currently prevailing leaf rust pathotypes (in the table, the ineffectiveness of *Lr26* is indicated by "*Lr26*" not being in bold font). It does however carry the APR gene *Lr34*. This variety is rated as highly resistant to leaf rust (R), which is due to the APR.
- Gazelle⸙ carries the ASR genes *Lr24* and *Lr37*, which again are not effective against currently prevailing pathotypes. This variety is rated as Moderately Resistant (MR), which must be due to APR. The genetic basis of this APR is, however, unknown ('uncharacterised').
- Note that although the variety Dart⸙ carries the APR gene *Lr34*, it is rated as being highly susceptible to leaf rust (S-VS). This is because some APR genes on their own do not provide strong levels of resistance (and is why they are sometimes referred to as 'minor genes', or 'genes of minor effect').

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.

Contact details

Robert F. Park
The University of Sydney
Mob: 0414 430 341
Email: robert.park@sydney.edu.au

⸙ Varieties with this symbol them are protected under the Plant Breeders Rights Act 1994.

Chickpeas – what we learnt in 2015 and recommendations for 2016

Note: Recommendations for Ascochyta were revised in May 2016 – please see related article in these proceedings

Kevin Moore, Leigh Jenkins, Paul Nash, Gail Chiplin and Sean Bithell, Department of Primary Industries, NSW

Key words

chickpea, Ascochyta, Phytophthora, management

GRDC code

DAN00176 Northern NSW Integrated Disease Management

Take home message

- Plant seed of known identity and purity and of high quality that has been properly treated with a registered seed dressing.
- Localities where Ascochyta was found on any variety in 2015 are considered high risk for 2016 crops and growers are advised to apply a preventative fungicide before the first post-emergent rain event to all varieties including PBA HatTrick⒫.
- Mild temperatures, long cloudy periods and frequent rainfall events during Jun/Jul across the Northern region as occurred in 2015, are ideal for early season outbreaks of Ascochyta blight in chickpea crops.
- In wet seasons the management of Ascochyta can be hindered by getting ground rigs into wet paddocks and shortage of fungicides.
- Follow the disease management recommendations in this article and associated links – they will maximise your chance of a profitable chickpea crop in 2016.

The 2015 northern NSW/southern QLD chickpea season

Unprecedented high prices (peaking at $900 in Jun) led to a record planting of chickpeas in the region. The 2015 winter crop season in northern NSW/southern QLD followed a wet Jan, dry Feb/Mar, wet Apr (except Dalby) and wet May (except Roma, Table 1).

In most centres in northern NSW, mild, wet to very wet conditions in Jun/Jul were followed by average or below average Aug, a very dry Sep, below average Oct rain and a wet Nov harvest. On the Downs conditions were much drier. Rainfall totals and long term averages for the Jun-Nov period were: Dubbo 292mm (LTA 279mm), Gilgandra 301mm (LTA 261mm), Trangie 251mm (LTA 225mm), Nyngan 204mm (LTA 190mm), Coonamble 158mm (LTA 231mm), Walgett 236mm (LTA 201mm), Moree 204mm (LTA 258mm), Tamworth 341mm (LTA 315mm), Roma 173 (LTA 226mm), Dalby 124mm (LTA 261mm) with monthly figures in Table 2.

With the exception of the Downs and western areas, these conditions, together with early sowing resulted in high biomass crops which used a lot of water. Cold, dry weather from late August to late September led to flower and pod abortion. This was not helped by considerable temperature fluctuations in the last 10-14 days of September (up to 20°C in a 24hr period). Hot, dry conditions in early October put crops under further stress (as most had run out of water). Thus, in many parts of northern NSW, seasonal conditions conspired to produce big canopies that ran out of water during the major pod filling period. Coupled with frosts, low and fluctuating temperatures, this resulted in missing pods, ghost pods or single-seed pods.

Table 1. Jan – May 2015 rain (mm) at selected locations in NSW/QLD

Location	Jan	Feb	Mar	Apr	May
Roma	86	31	33	46	12
Dalby	107	49	13	11	86
Dubbo	131	32	8	82	48
Gilgandra	103	21	3	99	73
Trangie	59	1	11	114	48
Nyngan	91	5	13	44	44
Coonamble	74	11	6	76	51
Walgett	34	0	6	24	30
Moree	105	4	60	63	33
Tamworth	90	23	52	86	38

Table 2. Jun – Nov 2015 rain (mm) at selected locations in NSW/QLD

Location	Jun	Jul	Aug	Sep	Oct	Nov
Roma	64	12	24	16	16	41
Dalby	10	18	24	15	47	9
Dubbo	72	60	39	8	46	67
Gilgandra	87	59	31	1	32	92
Trangie	44	44	33	3	28	99
Nyngan	51	35	29	7	13	70
Coonamble	39	27	13	4	29	35
Walgett	58	44	27	1	34	72
Moree	62	36	11	4	10	83
Tamworth	109	34	54	24	50	71

Nevertheless, in NSW yields east of the Castlereagh and Newell highways were generally good with the better crops going 2.5 – 3.0 t/ha. However, farmers west of these highways were disappointed with some crops yielding less than 0.2 t/ha.

In QLD, some crops on the Downs planted on wide rows went >3.0 t/ha with at least one Kyabra⁽ᴰ crop going 3.6 t/ha. The Downs crops were sown on a full profile but with in-crop rainfall well below average, they did not have a lot of biomass. This, coupled with wide rows which allowed the soil to warm up, is believed to account for the large yield differences between crops at say Dalby and those at Moree.

Chickpea diseases in 2015

In 2015, 243 crop inspections were conducted as part of DAN00176. Ascochyta blight, AB (*Phoma rabiei* formerly called *Ascochyta rabiei*) was detected in 60 crops. High chickpea prices tempted some growers to break rules, eg plant back to back chickpeas and they paid the price, in terms of AB infection and AB management costs in 2015 chickpea crops that followed 2014 chickpeas. Some growers reported more AB in PBA HatTrick⁽ᴰ than they ever saw in Jimbour, but many of these crops had been inundated in Jun/Jul and we know that AB resistance of waterlogged chickpeas is compromised. Further the genetic purity of the variety could not be determined. Generally, however, good management and dry conditions through Aug – Oct kept AB under control and no major yield losses were reported.

Phytophthora root rot, PRR (*Phytophthora medicaginis,* 23 cases) caused light to moderate losses but only in paddocks with a history of medics or where the susceptible variety PBA Boundary⁽ᴰ was planted.

The mild wet winter also favoured Sclerotinia (24 cases) especially in paddocks with a canola history, with both basal and aerial infections detected. Where canola was involved, the species was always *S. sclerotiorum*. One crop in the wetter areas east of Narrabri had aerial infection from ascospores of *S. minor* instead of the typical infection of roots and stem base by mycelia from sclerotia. This was the first record in this region for infection from windborne ascospores from sclerotia (due to carpogenic germination of sclerotia) leading to infection of chickpea by of *S. minor*. If such windborne infection is common, greater *S. minor* infection may result.

Botrytis Grey Mould, BGM (*Botrytis cinerea*) threatened to be a problem in high biomass crops and some of these were sprayed with carbendazim in early spring. This together with the hot dry finish, diminished the risk of BGM and no damage was reported.

Across the region, viruses were uncommon only reaching damaging levels in crops with poor, patchy stands (often the result of early season waterlogging) or where weeds had not been controlled.

Herbicide injury (Groups B, C, & I) was detected in most crops during Jun/Jul inspections including one striking example of damage predisposing a crop of PBA HatTrickⓓ at Billa Billa to PRR. Overall, herbicides caused no serious yield loss.

Disease management recommendations for 2016

Seed treatment and seed purity

Seed borne Botrytis, seed borne Ascochyta and several soil borne fungi can cause pre- and post-emergence seedling death. Irrespective of source of seed and year of production all chickpea planting seed should be treated with a registered seed dressing (Table 3). Proper coverage of the seed with an adequate rate of product is essential. Be confident of the identity and purity of your planting seed. If unsure acquire certified seed from a reputable seed merchant.

Table 3. Chickpea seed treatments

Active ingredient	Example Product	Rate	Target disease
thiabendazole 200 g/L+ thiram 360 g/L	P-Pickel T®	200 mL/100 kg seed	Seed-borne Ascochyta, Botrytis, Damping off, Fusarium
thiram 600 g/L	Thiram 600	200 mL/100 kg seed	Seed-borne Botrytis and Ascochyta, Damping off
thiram 800 g/kg	Thiragranz®	150 g/100 kg seed	Seed-borne Botrytis and Ascochyta, Damping off
metalaxyl 350 g/L	Apron® XL 350 ES	75 mL/100 kg seed	Phytophthora root rot

Ascochyta blight

Recommendations for Ascochyta were revised in May 2016 – please see related article in these proceedings

The following strategy should reduce losses from Ascochyta in 2016:

- In areas where AB was detected in 2015, spray all varieties, including PBA HatTrickⓓ and PBA Boundaryⓓ with a registered Ascochyta fungicide prior to the first rain event after crop emergence, three weeks after emergence, or at the 3 branch stage of crop development, whichever occurs first.
- In areas where AB was NOT detected in 2015, spray all varieties with AB resistance lower than PBA HatTrickⓓ with a registered Ascochyta fungicide prior to the first rain event after crop

emergence, three weeks after emergence, or at the 3 branch stage of crop development, whichever occurs first.

- 2-3 weeks after each rain event, monitor all crops irrespective of variety and spray if Ascochyta is detected in the crop or is found in the district on any variety.
- Ground application of fungicides is preferred. Select a nozzle such as a DG TwinJet or Turbo TwinJet that will produce no smaller than medium droplets (ASAE) and deliver the equivalent of 80–100 litres water/hectare at the desired speed.
- Where aerial application is the only option (e.g. wet weather delays) ensure the aircraft is set up properly and that contractors have had their spray patterns tested.

Botrytis grey mould, BGM

In areas outside Central Queensland, spraying for BGM is not needed in most years. However, if conditions favour the disease it will develop even though BGM was not a problem in 2015. Thus, in situations favourable to the disease (high biomass, average daily temperature 15 ^{o}C or higher, overhead irrigation in spring), a preventative spray of a registered fungicide before canopy closure, followed by another application 2 weeks later will assist in minimising BGM development in most years. If BGM is detected in a district or in an individual crop particularly during flowering or pod fill, a fungicide spray should be applied before the next rain event. None of the fungicides currently registered or under permit for the management of BGM on chickpea have eradicant activity, so their application will not eradicate established infections. Consequently, timely and thorough applications are critical.

Phytophthora root rot

Phytophthora root rot is a soil and water-borne disease, the inoculum can become established in some paddocks. Alternative Phytophthora hosts such as pasture legumes, particularly medics and lucerne must be managed to provide a clean break between chickpea crops. Damage is greatest in seasons with above average rainfall but only a single saturating rain event is needed for infection. Avoid high-risk paddocks such as those with a history of Phytophthora in chickpea, water logging or pasture legumes, particularly medics and lucerne. If considerations other than Phytophthora warrant sowing in a high-risk paddock, choose PBA HatTrick⊕ or Yorker⊕ and treat seed with metalaxyl. Metalaxyl can be applied in the same operation as other seed dressings providing all conditions of permits and labels are met. Metalaxyl only provides protection for about 8 weeks; crops can still become infected and die later in the season.

Further information

http://www.grdc.com.au/Resources/Factsheets/2013/05/Chickpea-disease-management and in the NSW DPI 2016 Winter Crop Variety Sowing Guide.

Acknowledgements

This research is made possible by the significant contributions of growers through both trial cooperation, paddocks access and the support of the GRDC, the authors would like to thank them for their continued support.

Contact details

Kevin Moore
Department of Primary Industries, Tamworth, NSW
Ph: 02 6763 1133 Mb: 0488 251 866 Fx: 02 6763 1100
Email: kevin.moore@dpi.nsw.gov.au

® Registered trademark

ⓓ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Chickpeas – new Ascochyta and Botrytis grey mould advice for 2016

Kevin Moore[1] and Johanna Couchman[2]

[1] Department of Primary Industries, NSW
[2] Department of Economic Development, Jobs, Transport and Resources, VIC

Key words

chickpea, Ascochyta, Botrytis, management

GRDC code

DAN00176 Northern NSW Integrated Disease Management

Take home message

- Guidelines for managing Ascochyta and Botrytis in 2016 have been revised as a result of changes to predicted winter and spring rainfall.
- Growers are advised to take a conservative approach to Ascochyta management and use an integrated management strategy of agronomy and fungicide application in Northern Region chickpea crops (with the exception of Central Queensland).
- Have at least 2-3 Ascochyta and 1-2 Botrytis fungicides on farm.
- In most situations, apply an Ascochyta fungicide to ALL varieties (including PBA HatTrick⦶ and PBA Boundary⦶) BEFORE the first post-emergent rain event.
- Be prepared to apply a BGM fungicide in early-mid September

Changes to the 2016 winter crop weather forecast

For the Northern Region the long term seasonal forecast has moved from predicted average early winter rainfall, and a probable El Niño, to above average winter rainfall combined with La Niña conditions in spring. This forecast, combined with evidence that the Ascochyta blight (AB) fungus is changing and concerns about varietal purity in the northern region, means chickpea growers will need to take a conservative approach to Ascochyta management. Mild, wet winter conditions will also produce high biomass crops and, combined with a wet spring, will favour Botrytis Grey Mould (BGM).

Reducing foliar disease risk through agronomy

Delaying planting will reduce the number of disease cycles to which the crop is exposed, however this increases the risk that it may start raining and remain too wet to plant. In this situation, planting on wider rows (75cm or greater) will provide better aeration, delayed canopy closure and improved penetration and coverage by foliar fungicides. Planting deeper will prolong emergence and achieve a similar result to delaying planting.

Be prepared – have fungicides on farm

There is a high possibility of a global shortage of chlorothalonil and mancozeb fungicides in 2016. If possible, stocking 3-4 Ascochyta sprays in high Ascochyta risk areas and 2-3 sprays in lower risk areas on farm would protect growers from such a shortage. There will also be strong demand for BGM fungicides from the lentil industry and growers are advised to have 1-2 BGM sprays available on farm. In addition, Pulse Australia has already obtained Minor Use Permits for alternative Ascochyta fungicides.

Be proactive with Ascochyta fungicide application

In the 2016 season, growers will face a few different scenarios with regard to Ascochyta management.

Irrespective of whether Ascochyta was detected in 2014 or 2015 in your district, all varieties rated Susceptible (S) (e.g. Kyabra⦷) or Moderately Susceptible (MS) (e.g. PBA Monarch⦷) should be treated with a registered Ascochyta fungicide before the first post emergent rain event. Central Queensland growers should consult with their agronomist.

In the following situations, it is recommended that growers spray with a registered Ascochyta fungicide BEFORE the first post emergent rain event:

- If Ascochyta was found in your district in 2014 or 2015;
- If Ascochyta was found on volunteers over the 2015/16 summer;
- If you are uncertain of purity of your variety - purity of your variety is best determined by asking yourself: How confident am I that every plant in my crop of PBA HatTrick⦷ is a HatTrick⦷ plant?
- If Ascochyta was not detected in your district in 2014 or 2015 and was not found on volunteers over 2015/16 summer, but you want to minimize your risk of Ascochyta.

If none of the above scenarios apply to your situation and you are prepared to accept some risk of Ascochyta, wait until Ascochyta is detected before activating a fungicide program. It should be noted that a lack of detection of Ascochyta in your crop or district does not mean it is not present. There have been several cases where Ascochyta was not detected in a previous crop, as was the case in 2014 and 2015, but became widespread on a subsequent crop or on volunteers.

Botrytis Grey Mould (BGM)

Unlike Ascochyta, if conditions favour BGM in 2016 it will occur irrespective of what has happened earlier in the season, including the use of Ascochyta fungicides. If the canopy is likely to close by mid to late September, apply a registered BGM fungicide. Consult your agronomist as to whether to apply a second BGM spray.

Acknowledgements

This research is made possible by the significant contributions of growers through both trial cooperation, paddocks access and the support of the GRDC, the authors would like to thank them for their continued support.

Contact details

Kevin Moore
Department of Primary Industries, Tamworth, NSW
Ph: 02 6763 1133
Mb: 0488 251 866
Fx: 02 6763 1100
Email: kevin.moore@dpi.nsw.gov.au

⦷ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Effect of chickpea ascochyta on yield of current varieties and advanced breeding lines – the 2015 Tamworth trial VMP15

Kevin Moore, Kristy Hobson, Steve Harden, Paul Nash, Gail Chiplin and Sean Bithell, Department of Primary Industries, Tamworth, NSW

Key words

Ascochyta, variety, management

GRDC code

DAN00176, DAN00151

Take home message

- Under extreme disease pressure, Ascochyta can be successfully and economically managed on susceptible varieties such as Kyabra⦶ and Jimbour⦶.
- However, Ascochyta management is easier and more cost effective on varieties with improved resistance eg PBA HatTrick⦶ and PBA Boundary⦶
- The 2015 Ascochyta trial, VMP15, confirmed the next variety planned for release (CICA0912) has excellent resistance to Ascochyta

2015 Tamworth Ascochyta management trial, VMP15

This trial sought to match Ascochyta blight (AB) management to a chickpea genotype's Ascochyta rating using ten varieties/advanced breeding lines with a range of Ascochyta resistance ratings: seven desis Kyabra⦶ (S, susceptible), PBA HatTrick⦶ (MR, moderately resistant), PBA Boundary⦶ (MR), CICA0912 (putatively R, resistant), CICA1007 (putatively MR), CICA1302 (for CQ, putatively MR) and CICA1303 (for CQ, putatively MR) plus the kabulis Genesis Kalkee™ (rated MS), PBA Monarch⦶ (MS, moderately susceptible) and Genesis 425™ (rated R).

There were three treatments: a regular fungicide application with regular applications of 1.0L/ha chlorothalonil (720g/L active), an alternative application variety management package (VMP) treatment with a low and off label rate of chlorothalonil; and a nil application; irrespective of treatment, all fungicides were applied before rain. Data for full rate and nil fungicide treatments only, are reported here (Table 1) because of restrictions on publishing off label results.

The trial was sown into standing cereal stubble on 18-19 May 2015 using tyne openers on 50cm row spacing in plots 4m wide by 10m long. VMP15 was split across two experiments, one on red soil, one on heavy black soil, the later had waterlogging problems which affected AB resistance (data not presented), data presented here are results for the trial on the red soil. We have seen examples of this in commercial crops of PBA HatTrick⦶ eg at Yallaroi in 2014 and Gulargambone in 2015 where waterlogging stress lead to a decline in AB resistance. On 16 Jun, when plants were at the 3 leaf stage, the trial was inoculated during a rainfall event with a cocktail of 20 isolates of Ascochyta collected from commercial chickpea crops (1999-2014) at a rate of 1,066,666 spores per mL in 200L/ha water. This early and heavy rate of inoculation combined with extremely favourable conditions resulted in high levels of Ascochyta disease, so much so that the unprotected susceptible varieties were dead by the end of July and even unprotected PBA HatTrick⦶ had severe damage (stem breakage). From inoculation to desiccation (1 Dec), the trial received 341mm in 46 days (32 days >1.0mm).

The first Group S VMP spray for Kyabra⦶ was applied before inoculation. The first Group MS VMP spray for Genesis Kalkee™, PBA Monarch⦶, CICA1302 and CICA1303 was applied after three infection events (6 rain days, 67 mm rain since inoculation), for Group MR VMP spray (PBA HatTrick⁽ᵇ⁾ and PBA Boundary⁽ᵇ⁾, CICA1007) and R (CICA0912, Genesis 425™) the first spray occurred after four infection events (14 rain days, 79 mm rain since inoculation). The number of rain days, rainfall and spray applications are summarised in Table 1.

Key findings of VMP15 (see Table 2) were:

- Under extreme disease pressure, Ascochyta can be successfully managed on susceptible varieties with frequent applications of registered rates of chlorothalonil
- Well managed Kyabra⁽ᵇ⁾ yielded 1862 kg/ha with a GM of $954/ha
- Under extreme disease pressure, unsprayed PBA HatTrick⁽ᵇ⁾ yielded only 417 kg/ha (GM -$4/ha)
- The new line CICA0912 performed well, yielding 1568 kg/ha (GM $844/ha) with no foliar fungicide

The performance of PBA HatTrick⁽ᵇ⁾ in VMP15 was both a surprise and a disappointment. In all previous VMP trials at Tamworth, unsprayed (Nil treatment) PBA HatTrick⁽ᵇ⁾ has produced substantial and profitable yields. For example in the 2010 trial, VMP10, it produced 1707 kg/ha (Table 3). 2010 also had above average rain in Jun/Jul that persisted throughout the season, so was in fact more conducive to Ascochyta than 2015 (although 2015 had more rain days in Jun/Jul than 2010).

VMP10 was sown 19 May 2010 using disc openers on 38cm row spacing in plots 4m wide by 10m long. There were four replicates (Table 3). On 17 Jun, when plants were at the 3 leaf stage, the trial was inoculated during a rainfall event with a cocktail of nine isolates of Ascochyta collected from commercial chickpea crops in 2008 and 2009 at a rate of 1 million spores per mL in 200L/ha water. From inoculation to desiccation (28 Nov), the trial received 430mm rain in 67 rain days (46 days >1.0mm) ie wetter than VMP15 both in total mm and number of rain days. Both VMP15 and VMP10 were in seasons that had regular rainfall and so supported the Ascochyta development consistently over the season and so provide a strong evaluation of current varieties and advanced breeding lines. A number of the key findings of VMP10 were similar to VMP15:

- Under extreme disease pressure, Ascochyta can be successfully managed on susceptible varieties with registered rates of chlorothalonil
- Well managed Jimbour⁽ᵇ⁾ yielded nearly 3t/ha with a GM of $750/ha
- The performance of varieties and advanced breeding lines with improved resistance to Ascochyta provided the best gross margins

The findings below contrasted between the two VMP experiments

- In 2010 PBA Boundary⁽ᵇ⁾ performed exceptionally well, yielding over 2t/ha without any foliar fungicide, a minimal yield loss (4%), compared with 53 % in 2015.
- Under extreme disease pressure in 2010 unsprayed HatTrick⁽ᵇ⁾ still gave a profitable yield, but unsprayed HatTrick⁽ᵇ⁾ yields were lower in 2015 and was not profitable

Table 1. VMP15 2015 dates, number of rain days (>1 mm rain), mm of rain and dates and number of 1 L/ha chlorothalonil applications, trial sown 18-19 May.

Date	No. days	mm Rain	1L spray
28-31 May	4	31	
12 Jun			Ist All genotypes
16*-19 Jun	4	61	
22 Jun	1	1	
30 Jun-01 Jul	2	4	
9 Jul			2nd All genotypes
10-17 Jul	8	12	
21 Jul			3rd All genotypes
24-27 Jul	4	13	
21 Aug			4th All genotypes
23-24 Aug	2	40	
1 Sep			5th All genotypes
3 Sep	1	11	
4 Sep	1	6	
16 Sep	1	4	
11 Oct			6th All genotypes
14 Oct	1	16	
22 Oct	1	18	
23 Oct	1	12	
26 Oct	1	10	7th All genotypes

*trial was inoculated with Ascochyta on 16 June 2015

The following factors in VMP15 may have contributed to the nil PBA HatTrick⚊ treatment having a poorer yield (Table 2) than in previous VMP trials (Table 3):

(a) parts of VMP15 were waterlogged during Jun/Jul; we know from past experience and commercial crops that any stress including waterlogging compromises PBA HatTrick's⚊ moderate resistance to Ascochyta.

(b) interaction between herbicide damage and Ascochyta resistance – VMP15 sustained minor herbicide injury in August. This may have also compromised PBA HatTrick's⚊ moderate resistance to Ascochyta.

(c) change in the pathogen; the isolates used in VMP10 were collected from crops in 2008 and 2009 compared to the isolates used in VMP15 which were collected from 1999 to 2014. Recently collected isolates have shown a higher level of agressiveness on PBA HatTrick⚊. See Ascochyta Variability GRDC Update paper for further information.

Table 2. Number and rate/ha of chlorothalonil sprays, cost of spraying, grain yield, and gross margin for seven desi and three kabuli chickpea varieties on red soil in the Tamworth VMP15 trial. (GMs also take into account other production costs estimated at \$300/ha; chickpea price desi \$730/t; kabuli \$1000/t) Yield $P<0.001$, LSD 417kg/ha; GM $P<0.001$, LSD \$354/ha

Variety	Rate of chlorothalonil	No. Sprays	Cost \$/ha	Yield kg/ha	GM \$/ha
CICA0912	1.0L	7	105	1853	984
Genesis425	1.0L	7	105	1875	1470
CICA1007	1.0L	7	105	1846	982
PBA BoundaryΦ	1.0L	7	105	1755	876
PBA MonarchΦ	1.0L	7	105	1274	869
PBA HatTrickΦ	1.0L	7	105	1722	852
CICA1302	1.0L	7	105	1864	954
CICA1303	1.0L	7	105	1949	1018
KyabraΦ	1.0L	7	105	1862	954
Kalkee	1.0L	7	105	1659	1254
CICA0912	Nil	0	0	1568	844
Genesis425	Nil	0	0	1144	844
CICA1007	Nil	0	0	1083	491
PBA BoundaryΦ	Nil	0	0	1233	600
PBA MonarchΦ	Nil	0	0	887	587
PBA HatTrickΦ	Nil	0	0	417	4
CICA1302	Nil	0	0	0	-300
CICA1303	Nil	0	0	0	-300
KyabraΦ	Nil	0	0	0	-300
Kalkee	Nil	0	0	1589	1289

Table 3. Number and rate/ha of chlorothalonil sprays, cost of spraying, grain yield, and gross margin for four desi chickpea varieties in the Tamworth VMP10 trial. (GMs also take into account other production costs estimated at $300/ha; chickpea price $450/t).

Variety	Rate of chlorothalonil	No. Sprays	Cost $/ha	Yield kg/ha	GM $/ha
Jimbour	1.0L	14	294	2988	750
[a]Kyabra⟠	1.0L	14	294	2549	553
PBA HatTrick⟠	1.0L	14	294	2604	578
PBA Boundary⟠	1.0L	14	294	2410	491
Jimbour	Nil	0	0	0	–300
Kyabra⟠	Nil	0	0	0	–300
PBA HatTrick⟠	Nil	0	0	1707	468
PBA Boundary⟠	Nil	0	0	2320	744

[a]Kyabra⟠ 1.0L one of the four reps was severely affected by water logging which (i) compromised Ascochyta control and (ii) impacted on yield

Acknowledgements

This research is made possible by the significant contributions of growers through both trial cooperation, field access and the support of the GRDC; the authors most gratefully thank them and the GRDC. Thanks to Woods Grains, Goondiwindi, Glen Coughran, "Beefwood", Moree and Joe Fleming, "Parraweena", Blackville for providing seed for the trials. We also thank agronomists for help with the crop inspections and submitting specimens, Gordon Cumming, Pulse Australia for industry liaison and chemical companies who provide products for research purposes and trial management.

Contact details

Kevin Moore
NSW DPI
Ph: 02 6763 1133
Mb: 0488 251 866
Fx: 02 6763 1100
Email: kevin.moore@dpi.nsw.gov.au

Kristy Hobson
NSW DPI
Ph: 02 6763 1174
Mb: 0400 955 476
Fx: 02 6763 1100
Email: kristy.hobson@dpi.nsw.gov.au

⟠ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

™ Registered Trademark

Chickpea on chickpea – is it worth it?

Kevin Moore, Kristy Hobson and Sean Bithell,
Department of Industry, NSW, Tamworth

Key words

chickpea, Ascochyta, Phytophthora, Sclerotinia, management

GRDC codes

DAN00176, DAN00151

Take home message:

Planting your 2016 chickpea crop into paddocks that had chickpeas in 2015, or earlier, is risky and you could lose money.

Further, it puts current disease management practices under pressure and could lead to reduced life of chickpea varieties, development of fungicide resistance and problems with weeds and insects.

Growers are urged to follow recommendations for current best practice especially with regard to crop rotation.

Background

Tempting as they are, current chickpea prices should not lure growers into thinking back to back chickpea is a viable option. Why not? For growers, the biggest risk is you stand to lose money – a lot of money. For the chickpea industry, the concern is that current best practices will become redundant prematurely or will fail completely.

What are the risks of back to back chickpea?

The main risks are seed borne, stubble borne and soil borne diseases. Successful disease management in chickpeas relies heavily on an integrated management package involving paddock selection (crop sequencing), variety choice, seed treatment, strategic fungicide use and hygiene.

Back to back chickpea - which diseases are of concern? There are four major chickpea diseases that will be favoured by planting chickpea on chickpea, ie:

- Ascochyta blight (AB, *Phoma rabiei* – previously called *Ascochyta rabiei*)
- Phytophthora root rot (PRR; *Phytophthora medicaginis*)
- Sclerotinia rot ("Sclero" *Sclerotinia sclerotiorum* and *S. minor*)
- Root lesion nematode (RLN, *Pratylenchus* spp)

Of these, Ascochyta, Phytophthora and Sclerotinia have the potential to cause 100% loss if conditions are conducive.

The risks of Botrytis grey mould (BGM, *Botrytis cinerea*), Botrytis seedling disease (BSD, *B. cinerea*) and viruses (several species) are unlikely to increase with chickpea on chickpea UNLESS some consequence of back to back chickpea favours these diseases eg patchy, uneven stands caused by Ascochyta, Sclerotinia or Phytophthora will increase the risk of virus.

If I did not find any disease in my 2015 crop, is it safe to plant chickpea on chickpea in 2016?

The short answer is NO. Severe disease can occur even if disease was not detected in the 2015 crop or even in earlier chickpea crops. This was demonstrated clearly in 2015 in north western NSW/southern QLD.

Case 1: The bulk of one paddock had been planted in 2013 to PBA HatTrickᶲ but a narrow strip was sown with the new variety PBA Boundaryᶲ. The soil was a clay grey vertosol conducive to Phytophthora root rot when wet. PBA HatTrickᶲ has some resistance to Phytophthora (rated MR) but PBA Boundaryᶲ is susceptible. In 2013, no Phytophthora was observed in either variety. The entire paddock grew wheat in 2014 and in 2015 was sown to PBA HatTrickᶲ. On 2 September 2015, Phytophthora (confirmed by lab test) was obvious in the area sown to PBA Boundaryᶲ in 2013 but was not detected in the bulk of the paddock sown to PBA HatTrickᶲ in 2013. The 2015 Phytophthora was so severe in the 2013 PBA Boundaryᶲ strip that it was not harvested whereas the 2013 PBA HatTrickᶲ area went over 2t/ha.

Case 2: In 2014 several paddocks on one farm were planted to Kyabraᶲ (susceptible to Ascochyta blight). Ascochyta was not detected in 2014 either on the farm or in the district. This, together with the prediction of an El Nino kicking in towards the end of July 2015, led to a decision to plant Kyabraᶲ in the paddocks that had Kyabraᶲ in 2014. It was reasoned that if Ascochyta did occur in 2015, it could be controlled with fungicides. What was not considered would be how to manage Ascochyta if it was too wet to spray – which unfortunately is what happened in early winter. Even though no Ascochyta was detected in 2014, the pathogen was clearly on farm and infected plants in late autumn/early winter. The first fungicide was not applied until 14 July by which time the disease was well established. When inspected on 29 July 2015, Ascochyta was rampant in all paddocks and was especially severe in those that had chickpeas in 2014, with many areas of dead and stunted plants. Although no rain fell after end July, these “bad” areas only went 0.6 – 0.8 t/ha compared with Kyabraᶲ planted into wheat stubble that went 1.0 – 1.5 t/ha.

What are the impacts of back to back chickpea on a grower?

The main short term one is losing money both from lost yield and quality and, for those diseases that can be controlled in-crop eg Ascochyta, increased production costs. Longer term consequences include increasing inoculum loads in paddocks, rendering them less productive and less flexible. For example with *Sclerotinia* spp, which have wide host ranges (including cotton), the survival structures (sclerotia) remain viable in soil for many years. Thus any practice that increases the sclerotial load reduces the potential of the paddock for host crops such as faba bean, canola, lupin, field pea, cotton (and future chickpea crops).

What are the impacts of back to back chickpea on the industry?

There are three:

1. Increased risk of changes in the pathogen ie it becomes more virulent and aggressive
2. Reduced commercial life of varieties ie back to back chickpea increases the risk of the pathogen establishing in the crop early which increases the potential for more disease cycles throughout the growing season which means resistance genes are subjected to more challenges by the pathogen. Resistance genes are limited; the loss of any gene will severely hinder the development of new chickpea varieties.
3. Increased risk of pathogens developing resistance to fungicides ie reduced life of fungicide. For diseases that can be managed with in-crop fungicides eg Ascochyta, the earlier the disease establishes, the more likely is the need for repeated applications of fungicides. If you wanted to find resistance to chlorothalonil in the Ascochyta pathogen, a good place to look would be in early sown back to back Kyabraᶲ. The problem here is that any isolate that is resistant to

chlorothalonil is unlikely to be confined to the paddock (or farm) in which that resistance developed. Thus an Ascochyta isolate with resistance to chlorothalonil on a single farm in say Moree could become established in the Darling Downs and elsewhere in northern and north central NSW within a few seasons. This would be the end of chlorothalonil as a disease management tool for chickpeas.

Planting 2016 chickpeas into 2015 chickpea paddocks – is it worth it?

Definitely NOT. Besides it is doesn't make sense. As well as increased risk of disease, weed and insect management will also be more challenging. At $800/t, surely growers should be doing everything to reduce risk and maximise yield and quality.

Further information on chickpea disease management can be found at the following:

http://www.grdc.com.au/Resources/Factsheets/2013/05/Chickpea-disease-management and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

This research is made possible by the significant contributions of growers through both trial cooperation, field access and the support of the GRDC; the authors most gratefully thank them and the GRDC. We also thank agronomists for help with the crop inspections and submitting specimens, Gordon Cumming, Pulse Australia for industry liaison and chemical companies who provide products for research purposes and trial management.

Contact details

Kevin Moore
Ph: 02 6763 1133
Mb: 0488 251 866
Fx: 02 6763 1100
Email: kevin.moore@dpi.nsw.gov.au

Kristy Hobson
Ph: 02 6763 1174
Mb: 0400 955 476
Fx: 02 6763 1100
Email: kristy.hobson@dpi.nsw.gov.au

Sean Bithell
Ph: 02 6763 1117
Mb: 0429 201 863
Fx: 02 6763 1100
Email: sean.bithell@dpi.nsw.gov.au

⅁ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Chickpea Ascochyta – latest research on variability and implications for management

Kevin Moore[1], Kristy Hobson[1], Nicole Dron[1], Prabhakaran Sambasivam[2], Rebecca Ford[,3], Steve Harden[1], Yasir Mehmood[3], Jenny Davidson[4], Shimna Sudheesh[5], Sukhjiwan Kaur[5] and Sean Bithell[1]

[1]Department of Primary Industries NSW, [2]University of Melbourne VIC, [3]Griffith University, QLD, [4]SARDI, SA, [5]Agribio DEDJTR, VIC

Key words

chickpea, Ascochyta, pathogenicity, latent period

GRDC code

DAN00176, UM00052, DAN00151, DAV00126, DAN00151, DAV00098

Take home message

- In 2015, Ascochyta blight occurred in a higher proportion of chickpea crops (60 of 243 crop inspections) than in 2014 (62 of 332 crop inspections). Most infected crops were PBA HatTrick⅄ which was also the most commonly grown variety.
- Work to determine if the Ascochyta pathogen is changing started in 2013, where a number of projects are working together to provide an integrated approach to chickpea Ascochyta blight to improve variety resistance and best management practices.
- Initial results show that the population varies in time for spore germination, germ tube length, ability to cause disease (pathogenicity), and time to develop fruiting bodies (latent period).
- Significant differences in the reaction of some varieties and advanced breeding lines to two aggressive isolates of the AB pathogen have been found
- It is essential that growers adhere to best management practices, such as sustainable rotations, to minimise selection pressure on the pathogen and maximise the longevity of variety resistance.
- While research into variability of the AB pathogen continues, it seems prudent to adopt a conservative approach to AB management

Ascochyta blight in 2015 chickpea crops

In 2015, 243 chickpea crop inspections were conducted as part of DAN00176. Ascochyta blight (AB) (*Phoma rabiei* formerly called *Ascochyta rabiei*) was detected in 60 crops. Inoculum had carried over from the 2014 season and wet conditions during Jun/Jul favoured infection and disease development. High chickpea prices tempted some growers to break best practice eg plant back to back chickpeas resulting in severe disease. Some growers reported more AB in PBA HatTrick⅄ than they ever saw in Jimbour but many of these crops had been inundated in Jun/Jul and we know that AB resistance of waterlogged chickpeas is compromised. Further the genetic purity of the variety could not be determined. Generally, however, good management and dry conditions through Aug – Oct kept AB under control and no major yield losses were reported.

Details of chickpea diseases and a review of the 2015 chickpea season are in another paper in these Proceedings (Chickpeas – what we learnt in 2015 and recommendations for 2016).

Latest research on variability in the Ascochyta pathogen

Is the pathogen changing? Yes, and as a population of living individuals (isolates), we should expect it to change.

Has the pathogen changed in response to selection pressure such as the widespread cultivation of varieties with improved resistance or other factors? We don't yet know. To know if something has changed, you need to track it over a suitable time period. Detailed studies on molecular variability in the AB fungus commenced in 2008 and have shown that the overall population variation hasn't changed much. However, pathogenicity studies that began in 2013 indicate that there are differences in pathogenicity among isolates and that highly pathogenic isolates are causing disease on PBA HatTrick. This paper provides key results from a range of research groups working on this combined project to better understand the chickpea AB population and its threat to the resistance sources through potential adaptation and selection.

Latent period

The incubation period is the time from infection to the appearance of symptoms. The latent period (LP) is the time from infection to the development of pycnidia (the small dark fruiting bodies that develop in the leaf and stem lesions), the LP is important because it determines how fast the disease can cycle in a crop. Determining these characteristics is thus another way of measuring variability in the pathogen population.

Three experiments were conducted in 2015. In each experiment, five isolates representing a sub-set of the pathogen population in Eastern Australia plus a 6th control isolate (obtained in 2014 from PBA HatTrick at Yallaroi, TR6415) were evaluated in a growth cabinet (20°C/15°C 12h day/12h night) on four chickpea genotypes. There were eight replicates (pots) for each of the 24 genotype by isolate combinations. At the 3 leaf stage plants were grouped by isolate and inoculated with a conidial suspension of 100,000 conidia/mL (sprayed to run-off). Plants were examined daily for symptoms and pycnidia. The mean LP was estimated by survival analysis with the status of a pot based on whether pycnidia had or had not developed. For each genotype-isolate, the data is the last day that pycnidia had not developed.

The four genotypes, their AB rating and abbreviation are: 1) ICC3996 (rated R, coded ICC), 2) Genesis™ 090 (rated R, coded GEN), 3) PBA HatTrick (rated MR, coded HAT), 4) Kyabra (rated S, coded KYB).

For each experiment, LP varied significantly between some isolates and genotypes (LP range 6-8 days). Furthermore, all isolates had the shortest LP on the most susceptible entry, KYB and the longest LP on the most resistant entry, ICC or the second most resistant entry, GEN (see example findings, Figure 1). Within an experiment, no single isolate had the shortest LPs on all genotypes, we interpret this as indicating there are no clear differences among isolates in the contribution of LP to isolate aggressiveness.

These experiments complement the pathogenicity work and confirm variability does exist in the pathogen population

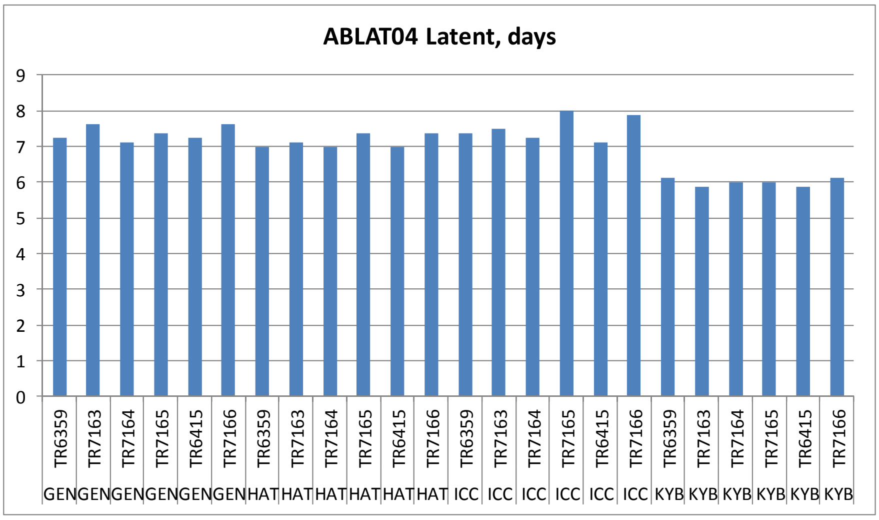


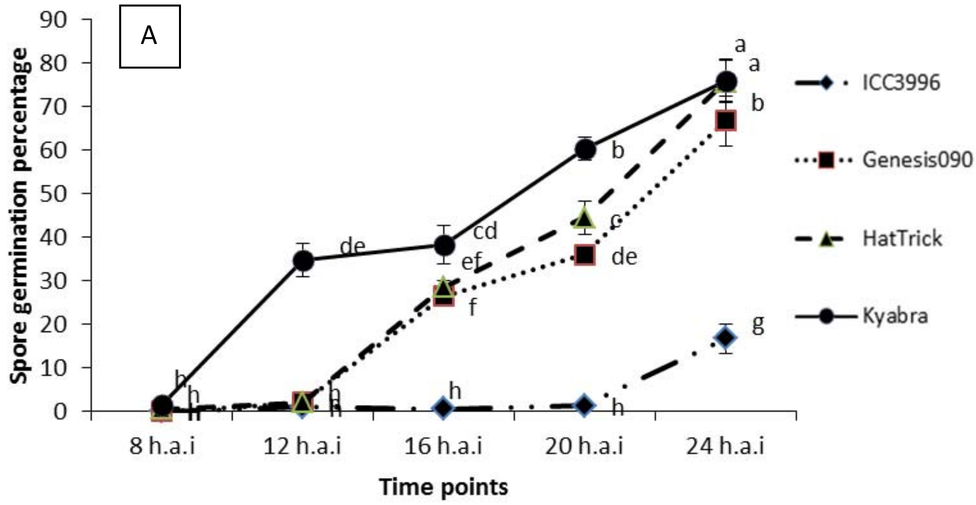
Figure1. Latent period results for experiment ABLAT04 grouped by genotype (ICC3996 (ICC), Genesis 090 (GEN), PBA HatTrickᶲ (HAT), Kyabraᶲ (KYB)) for inoculation with six isolates listed by isolate no, source and variety: TR6359 2014 North Star NSW, Flipperᶲ; TR7165 2014 Horsham VIC; Genesis425, TR7163 2014 Donald VIC; Slasherᶲ; TR6415 2014 Yallaroi NSW, HatTrickᶲ; TR7164 2014 Donald VIC, Slasherᶲ; TR7166 2014 Salter Springs SA, Monarchᶲ.

Histopathology experiments

A range of preliminary histopathology experiments have been completed, see Figure 2 for summary spore germination and germ tube length results. Key findings from a range of work in this area are that:

- Spore germination begins much faster on the susceptible Kyabraᶲ and on PBA HatTrickᶲ than on the resistant Genesis090
- Spore germination is consistently slower and lower on the resistance source ICC3996 than on any other chickpea genotype tested
- There is significant variation in germination time among different isolates and this correlates with their level of pathogenicity
- After germination, germ tube length prior to invasion is significantly shorter on ICC3996 than any other chickpea genotype tested

These differential fungal responses may be indicative of host recognition and defence strategies, which are being further investigated.



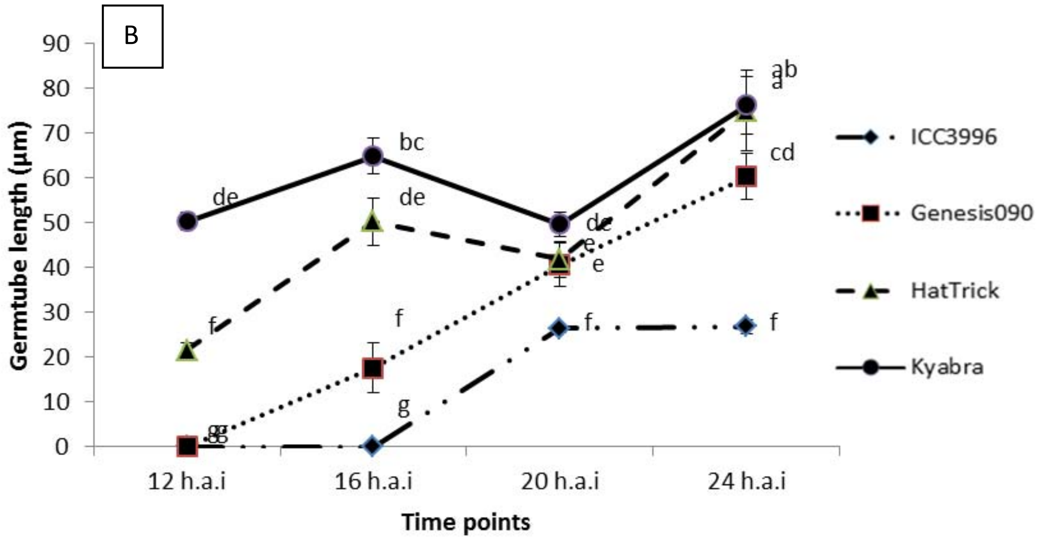


Figure 2. Significant differences were observed among the physiological traits of a highly pathogenic isolate FT13092-1 from Kingsford, SA when inoculated onto chickpea genotypes that are resistant (ICC3996 and Genesis090), moderately resistant (PBA HatTrick) or susceptible (Kyabra). Where A = the percentage of germinated spores and B = the germtube length over time after inoculation.

How is this information used by the PBA Chickpea program?

In 2014 and 2015 two aggressive isolates identified by the pathogen variability project were screened on the national Stage 3 desi and kabuli entries in a controlled environment by SARDI. In 2015 the two isolates tested were collected in 2013; FT13092-1 from South Australia on Genesis 090 and TR5919 from northern NSW (Tooraweenah) on PBA HatTrick. Of the 154 entries tested, 62 breeding lines significantly differed in their resistance (% of main stem broken) to the two isolates (subset of lines presented in Table 1). The northern isolate was found to be more aggressive than the South Australian isolate. There was no significant difference in the response of PBA HatTrick to the two isolates, but PBA Boundary, CICA0912 and CICA1007 had significantly higher disease with TR5919. Conversely, the kabuli variety Genesis Kalkee had significantly lower disease with the TR5919 isolate compared to the SA isolate. The desi CICA1521 and kabuli CICA1156 had very low levels of disease from both isolates. The 2014 research examined two isolates collected in 2010 and a much smaller number of entries 8 (out of 137) had a significantly different response to the two isolates.

To complement this information, molecular markers have been screened across the 154 entries. A total of 5 flanking molecular markers (3 SNPs and 2 SSRs) for AB resistance (resistance sources S95362 (kabuli) and ICC3996 (desi)) were identified within “DAV00098 - Molecular markers for the pulse breeding programs” led by DEDJTR, Victoria. These markers have been validated across a diverse set of chickpea lines as part of DAV00126 program. By combining the phenotypic and genotypic information, the breeding program will gain a greater understanding of the genetic resistance in each breeding line. The wider implementation of AB molecular markers across the PBA Chickpea program has identified breeding material which may contain alternative resistance genes. Research into alternative genetic resistance genes is continuing in DAV00126. The use of alternative resistance genes in the breeding program will be essential to ensure new chickpea varieties have adequate levels of AB resistance.

Table 1. Ascochyta blight ratings, response of varieties and breeding lines (% main stems broken, lsd 29.2) to two *Phoma rabiei* isolates in a controlled environment and presence/absence (+/-) of molecular marker and source of resistance.

	AB	% of main stems broken		
Name	Field rating	Isolate FT13092-1	Isolate TR5919	Marker genotype
Kyabra⦶	S	100	100	-
PBA HatTrick⦶	MR	0	20	+, desi
PBA Boundary⦶	MR	35	75	+, desi
Genesis 836	MS	8	28	Not conclusive
CICA0912	R*	0	42	+, desi
CICA1007	MR*	0	50	+, desi
CICA1521	R*	0	8	+, desi
Almaz⦶	MS	8	8	-, suggests other genes
Genesis 090	R	0	8	+, kabuli
Genesis 425	R	8	17	+, kabuli
Genesis Kalkee	MS	50	20	--, suggests other genes
PBA Monarch⦶	MS	3	42	+, kabuli plus others
CICA1156	R*	0	0	+, kabuli

*Advanced breeding lines, putative AB rating

While research into variability of the AB pathogen continues, it seems prudent to adopt a conservative approach to AB management

Further information

http://www.grdc.com.au/Resources/Factsheets/2013/05/Chickpea-disease-management and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

This research would not be possible without the considerable and ongoing support from growers and the GRDC for which we are most grateful. Thanks to Paul Nash and Gail Chiplin for technical support. Thanks also to agronomists for help with the crop inspections and submitting specimens.

Contact details

Kevin Moore
NSW DPI
Ph: 02 6763 1133
Mb: 0488 251 866
Fx: 02 6763 1100
Email: kevin.moore@dpi.nsw.gov.au

Kristy Hobson
Ph: 02 6763 1174
Mb: 0400 955 476
Fx: 02 6763 1100
Email: kristy.hobson@dpi.nsw.gov.au

® Registered trademark

⚘ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Phytophthora in chickpea varieties HER15 trial –resistance and yield loss

Kevin Moore[1], Lisa Kelly[2], Kristy Hobson[1], Steve Harden[1], Willy Martin[3], Kris King[3], Gail Chiplin[1] and Sean Bithell[1]

[1] NSWDPI Tamworth; [2] DAFQ Toowoomba; [3] DAFQ Warwick

Key words

Phytophthora root rot, variety, risk management

GRDC code

DAN00176, DAN00151, DAQ00186, DAS00137

Take home message

- In a wet season, substantial (94%) yield losses from PRR occur in susceptible varieties such as PBA Boundary⦶. Do not grow PBA Boundary⦶ if you suspect a PRR risk
- Varieties with improved resistance to PRR (PBA HatTrick⦶ and Yorker⦶) can also have large yield losses (68-79%) in a very heavy PRR season
- Although yield losses will occur in very heavy PRR seasons, crosses between chickpea and wild *Cicer* species such as the breeding line CICA1328 offer the best resistance to PRR
- Avoid paddocks with a history of lucerne, medics or chickpea PRR

Varietal resistance to phytophthora root rot

Phytophthora medicaginis, the cause of phytophthora root rot (PRR) of chickpea is endemic and widespread in southern QLD and northern NSW, where it carries over from season to season on infected chickpea volunteers, lucerne, native medics and as resistant structures (oospores) in the soil. Although registered for use on chickpeas, metalaxyl seed treatment is expensive, does not provide season-long protection and is not recommended. There are no in-crop control measures for PRR and reducing losses from the disease are based on avoiding risky paddocks and choosing the right variety.

Detailed information on control of PRR in chickpea is available at:
http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/phytophthora-root-rot

Current commercial varieties differ in their resistance to *P. medicaginis*, with Yorker⦶ and PBA HatTrick⦶ having the best resistance and are rated MR (historically Yorker⦶ has been slightly better than PBA HatTrick⦶), while Jimbour is MS - MR, Flipper⦶ and Kyabra⦶ are MS and PBA Boundary⦶ has the lowest resistance (S). PBA Boundary⦶ should not be grown in paddocks with a history of PRR, lucerne, medics or other known hosts such as sulla.

From 2007 to 2015 PRR resistance trials at the DAF Qld Hermitage research Facility, Warwick QLD have evaluated a range of varieties and advanced PBA breeding lines. Each year the trial is inoculated with *P. medicaginis* at planting. There are two treatments, (i) seed treatment with thiram + thiabendazole and metalaxyl and regular soil drenches with metalaxyl (Note: soil drenches with metalaxyl not currently registered) and (ii) seed treatment with thiram + thiabendazole only with no soil drenches. The first treatment has prevented infection by the PRR pathogen in all of these trials. The difference in yield between the metalaxyl-treated plots and untreated plots are used to calculate the yield loss caused by PRR i.e. % loss = 100*(Average yield of metalaxyl-treated plots – Average yield of nil metalaxyl plots)/ Average yield of metalaxyl-treated plots.

Yields in metalaxyl-treated plots were close to seasonal averages for the 2015 season with the lowest yielding breeding lines and varieties (CICA1328, Yorker and PBA HatTrick) yielding close to 2.5 t/ha (Table 1).

In 2015 the level of PRR in the trial was considerably higher than those previous seasons such as 2014 (Table 2). For example yield losses were greater than 40% for CICA1328 in 2015 but only 1.8% in 2015 and yield losses for PBA Boundary were 94% in 2015 and 74% in 2014. However, the 2015 trial again confirmed that Yorker and PBA HatTrick had better resistance than PBA Boundary (Table 1), which has been consistent across previous trials.

Results for the high PRR disease season of 2015 showed that susceptible varieties sustain substantial yield loss from PRR and that varieties with moderate resistance have reduced losses. The 2015 trial again confirmed the superior PRR resistance of the PBA breeding line CICA1328 which is a cross between a chickpea (*Cicer arietinum*) line and a wild *Cicer* species.

CICA1007 was included in the 2015 trial because it has high yield and large seed size in a Yorker background. In the absence of PRR it was the second highest yielder in the trial (2.93t/ha) and its yield loss to PRR was similar to Yorker.

Table 1. Yields of commercial chickpea varieties and breeding lines protected from Phytophthora root rot, and % yield losses from PRR in a 2015 trial at Warwick QLD. (P Yield<0.001; lsd Yield = 0.46)

Variety/line[A]	Yield (t/ha) in absence of *Phytophthora* infection	Yield (t/ha) in presence of *Phytophthora* infection	% yield loss due to *Phytophthora* infection
CICA1328[A]	2.64	1.54	41.7
D06344>F3BREE2AB027[A]	2.52	1.05	58.4
PBA HatTrick	2.50	0.81	67.7
Yorker	2.61	0.57	78.7
CICA1007	2.93	0.71	75.9
CICA0912	2.76	0.37	86.6
PBA Boundary	2.88	0.17	94.0

[A] These lines are crosses between chickpea (*C. arietinum*) and a wild *Cicer* species

Table 2. Yields of commercial chickpea varieties and breeding lines protected from Phytophthora root rot, and % yield losses from PRR in a 2014 trial at Warwick QLD. (P Yield<0.05; lsd Yield = 0.80)

Variety/line[A]	Yield (t/ha) in absence of *Phytophthora* infection	Yield (t/ha) in presence of *Phytophthora* infection	% yield loss due to *Phytophthora* infection
CICA1328[A]	2.76	2.71	1.8
Yorker	3.01	2.69	10.4
CICA1211	3.01	2.66	11.6
D06344>F3BREE2AB027[A]	2.93	2.13	27.4
PBA HatTrick	2.94	1.98	32.8
CICA0912	3.23	1.79	44.6
PBA Boundary	2.79	0.73	73.8

[A] These lines are crosses between chickpea (*C. arietinum*) and a wild *Cicer* species

Acknowledgements

Thanks to growers and agronomists for help with crop inspections and submitting specimens, to Woods Grains, Goondiwindi for planting material for trials and to chemical companies who provided products for research purposes and trial management.

This research is made possible by the significant contributions of growers through both trial cooperation, field access and the support of the GRDC, the authors would like to thank them for their continued support.

Contact details

Kevin Moore
NSW Department Primary Industries
Mb: 0488 251 866
Fax: 02 6763 1100
Email: kevin.moore@dpi.nsw.gov.au

⊕ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

How much can pulse agronomy affect the amount of nitrogen fixed?

Nikki Seymour[1], RCN Rachaputi[2], Kerry McKenzie[1], Stephen Krosch[1]

[1]Department of Agriculture and Fisheries, Queensland

[2]Queensland Alliance of Agriculture and Food Innovation

Key words

Pulses, nitrogen fixation, nitrogen balance, row spacing

GRDC codes

DAQ00180, DAQ0018, UQ00067

Take home message

The amount of N fixed by a pulse crop is largely influenced by how well that crop grows. More crop biomass =more N fixed by that crop provided it is well nodulated.

The amount of N fixed by a legume does not equal the amount available for the next crop. N is removed in the harvested grain and that N remaining in the crop residue then needs to be mineralised by microbial activity before it is available to the next crop.

Row spacing in chickpeas of 0.25 lead to greater biomass, yield and increased N fixation than at 1.0m. N fixation in mungbeans is also significantly better at narrower row spacing particularly in recent varieties.

High soil N levels can significantly reduce N fixation.

Sowing at the optimum time for maximum crop biomass leads to greater amounts of N fixed.

Background

Average amounts of N fixed annually by crop and pasture legumes are around 110 kg N/ha (ranging from close to zero to more than 400kg N/ha). The actual amount fixed depends on the species of legume grown, the site and the seasonal conditions as well as agronomic management of the crop or pasture. The legume crop uses this N for its own growth and may fix significantly more than needed, leaving a positive N balance in the soil for proceeding crops.

Chickpeas were the most widely grown legume crop in Australia in 2013 with about 85 per cent being grown in NSW and Queensland. Mungbeans in the years 2008 - 2010 were up to 70000 t average production after an average of just 40000 t in 2004 -2007, mainly through improved average yields. The vast majority are grown in the northern region of Australia.

The amount of N fixed by a legume increases as legume biomass increases but is reduced by high levels of soil nitrate. In general, legume reliance on N fixation is high when soil nitrate levels are below 50 kg N/ha in the top metre of soil. Above 200 kg N/ha, nitrogen fixation is generally close to zero. The fixed N is used for the growth of the legume itself (saving fertiliser application of the legume crop) as well as potentially leaving residual N for the following cereal or oilseed crop and providing a break from cereal stubble and soil-borne diseases.

Work by Doughton *et al.* (1993) clearly demonstrated the impact of increasing soil nitrate levels on N fixation of chickpeas (see Figure 1), with no yield advantage being gained by applying N. Moreover, chickpea provided a positive soil N balance when fixation rates were high and a negative balance at low fixation rates.

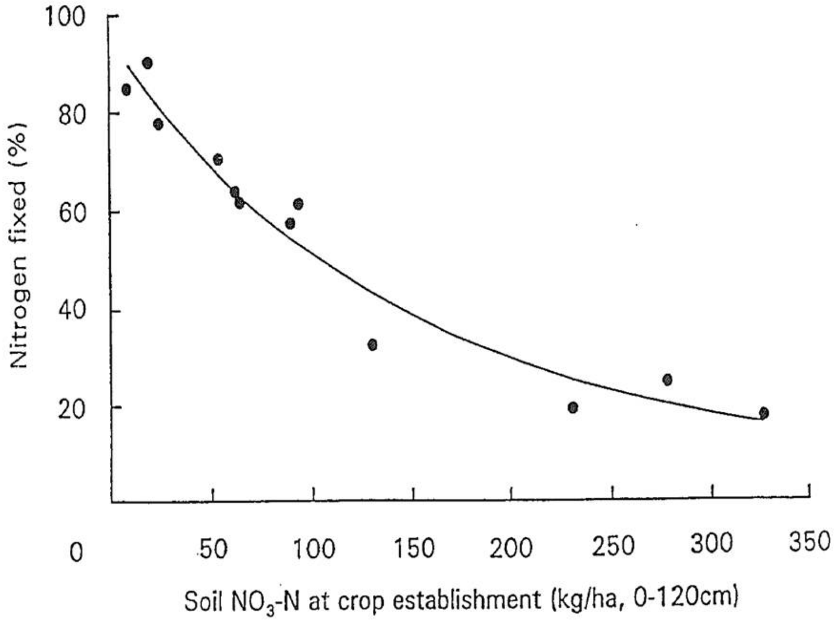


Figure 1. Per cent nitrogen fixed in chickpea (cv. Reselected Tyson) tops 130 days after planting for various levels of soil NO_3-N at crop establishment. For fitted curve, $Y = 7.05+88.45e^{-0.0070X}$, $R^2 = 0.95$ (from Doughton *et al.* 1993).

Agronomy influences N fixation

The impacts of varying agronomic practices on N fixation are being assessed on trials grown in different environments under the GRDC Pulse Agronomy Initiative in the northern region.

Row spacing

Two chickpea trials conducted recently on the Downs (near Goondiwindi and Dalby) were assessed for the amount of N fixation at different row spacings (all at the same plant population of 30 plants/m^2.) Yields were considerably lower at the Goondiwindi site (ranged from 1.5 to 2.1 t/ha) compared to the Dalby site (from 3.2 to 4.7 t/ha) due largely to better seasonal conditions at Dalby, and there was a significant site x genotype x row spacing interaction. Generally, yield and biomass production were reduced as row spacing increased but the amount differed for each genotype. There were no differences in N fixation amongst varieties but row spacing significantly decreased the percent of N fixation (also called %N derived from the atmosphere or %Ndfa) and the total amount of N fixed, particularly at the Dalby site (Table 1).

Up to 59 kg N/ha remained at the Dalby site when chickpeas were grown on 0.25m rows but only 23 kg N/ha from the 1.0 m row spacing. At Goondiwindi, the net N balance ranged from 6 down to -6 kg N/ha as row spacing increased from 0.25m to 1.0m. As a crops' demand for N increased so did the N fixation by that crop as seen at our Dalby trial grown under better seasonal conditions.

Table 1. Reduction in biomass, N fixation (%N derived from the atmosphere or %Ndfa) and total amount of N fixed in chickpea (meaned across 3 genotypes) as row spacing in the field increases.

	Shoot dry weight (t/ha)		%Ndfa		Total crop N fixed (kg/ha)		N balance (kg/ha)	
Row spacing (m)	Dalby	Goondi	Dalby	Goondi	Dalby	Goondi	Dalby	Goondi
0.25	9.89	4.75	61.0	39.2	187.3	62.8	59	6
0.5	9.25	4.23	55.8	33.9	161.9	48.0	45	-5
1.0	7.96	3.59	47.6	35.4	122.5	42.0	23	-6
LSD (P=0.05)	1.12	0.67	7.0	n.s.	31.5	16.3	n.s.	n.s.

In trials with mungbeans in Qld, differences in the amount of nitrogen fixed was evident between varieties and the row spacings across all varieties (Figure 2).

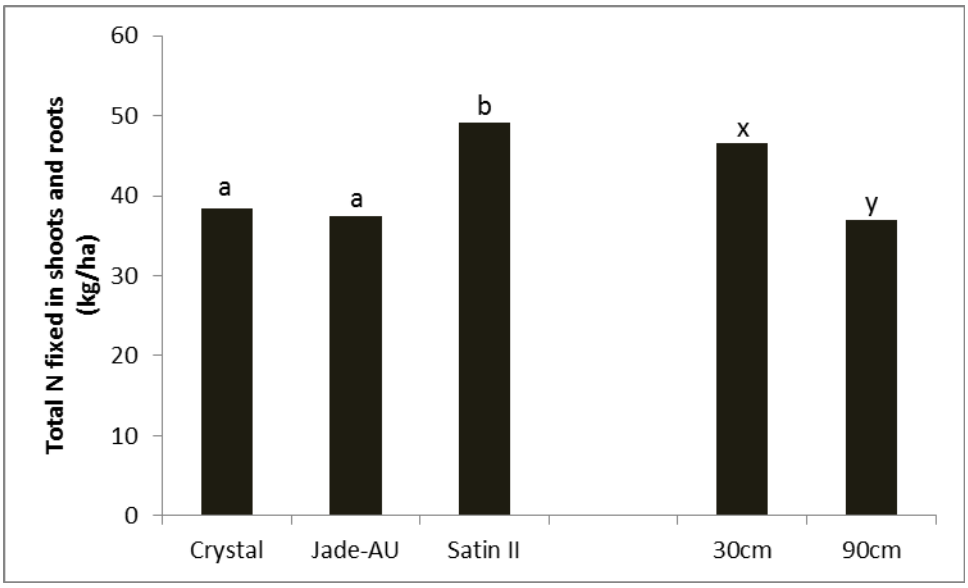


Figure 2. Differences in total shot and root nitrogen by variety (LSD 5% = 7.65) and row spacing (LSD 5% = 6.24), Kingaroy 2012/13

The differences in the amount of N in the shoots and roots (Figure) can be influenced by the amount of total dry matter produced or the percent of nitrogen derived from the atmosphere (%Ndfa). It can be seen in **Figure** that the amount of nitrogen derived from the atmosphere for Crystal ⒫ and Jade-AU ⒫ was different with changes in row spacings, however Satin II ⒫ kept the amount of N from the atmosphere constant at the varying row spacings.

As we have shown with the other trial results narrower rows are producing higher yields which must be supported by higher dry matter production. The crop then has a higher nitrogen demand that is being met by an increase in the nitrogen fixed by rhizobia and provided to the plant.

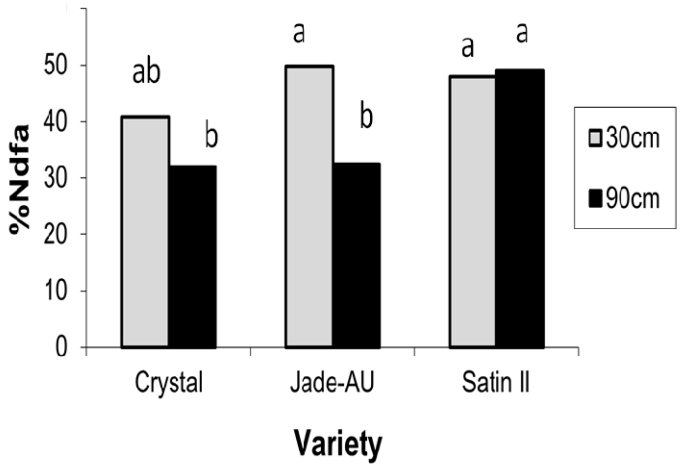


Figure 3. %Ndfa of different varieties at 2 row spacings, Kingaroy 2012/13 (LSD 5% = 9.28).

Time of sowing

Sowing on time to take full advantage of soil water and growing conditions that maximise crop production can make a significant impact on amount of N fixed. The graph below gives an indication of the impact that time of sowing of soybeans can have on N fixation comparing soybeans planted in the middle of the appropriate planting window with late in that window . Figure 4 shows that for two different soybean varieties (NF246-64 and PR443) as much as 150kg/ha less N is fixed due to the shortened growing season. However, increasing the plant population becomes very important for improving the proportion of N that is fixed if time of sowing is delayed (Figure 5).

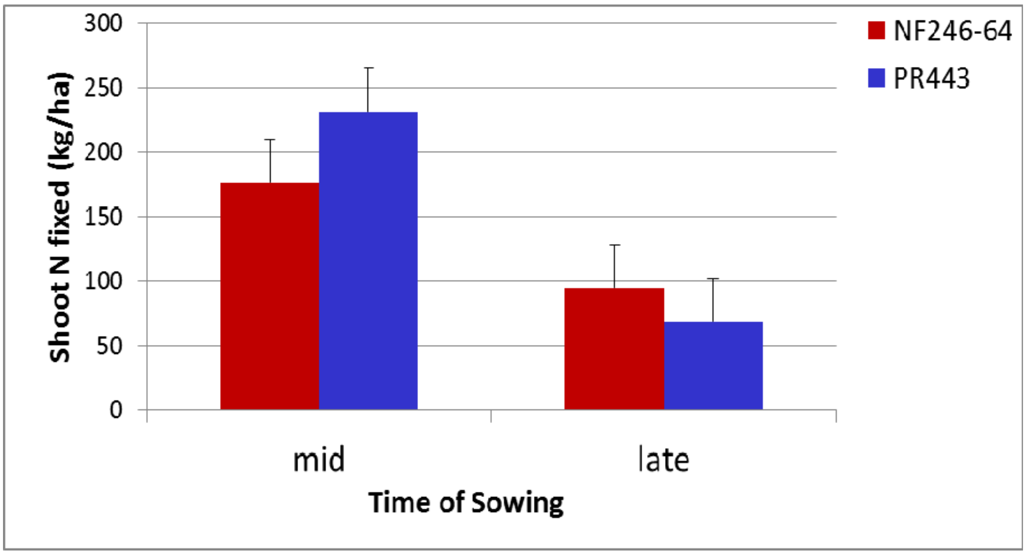


Figure 4. Nitrogen fixation is reduced when soybeans are sown late in the planting window (LSD 5%=33).

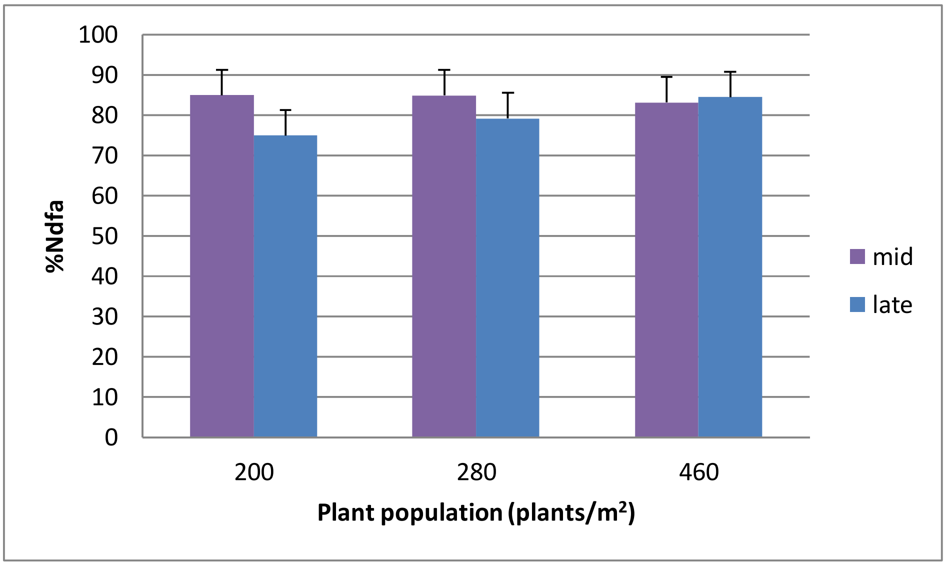


Figure 5. Higher plant populations compensate partially for a later planted soybean crop in terms of N fixation (LSD (5%) = 8.7).

Impact of applied fertilisers

Field trials conducted in Central Queensland in mungbean showed that nodulation was suppressed by applications of urea at rates of 10 or more kg N/ha or Triple Super at 5 or 10 kg P/ha (Figure 6). Also, no yield advantage was gained by the addition of fertiliser N (Figure 7) (Seymour *et al.* 2010). Pre-plant soil nitrate levels at this site started at about 80kg N/ha in the top 1m and were increased from there with applied fertilisers. There was also a history of mungbeans at this site contributing to the nodulation of the uninoculated treatments. Despite this, there was a significant yield response to inoculation.

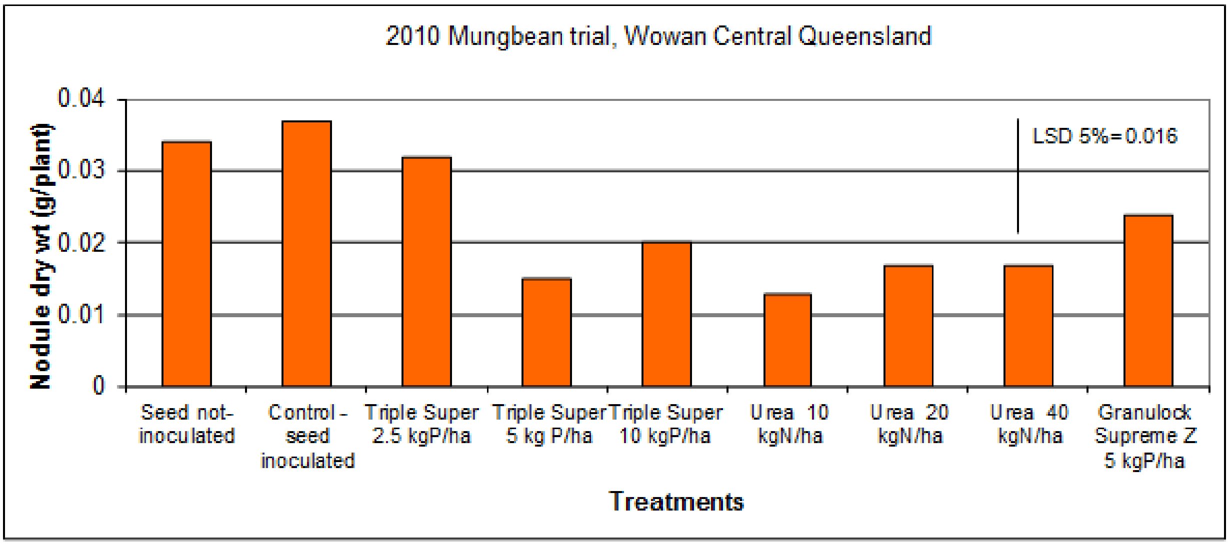


Figure 6. Impact on nodulation of mungbean cv. Crystal⒫ from rhizobial inoculation and preplant fertiliser applications.

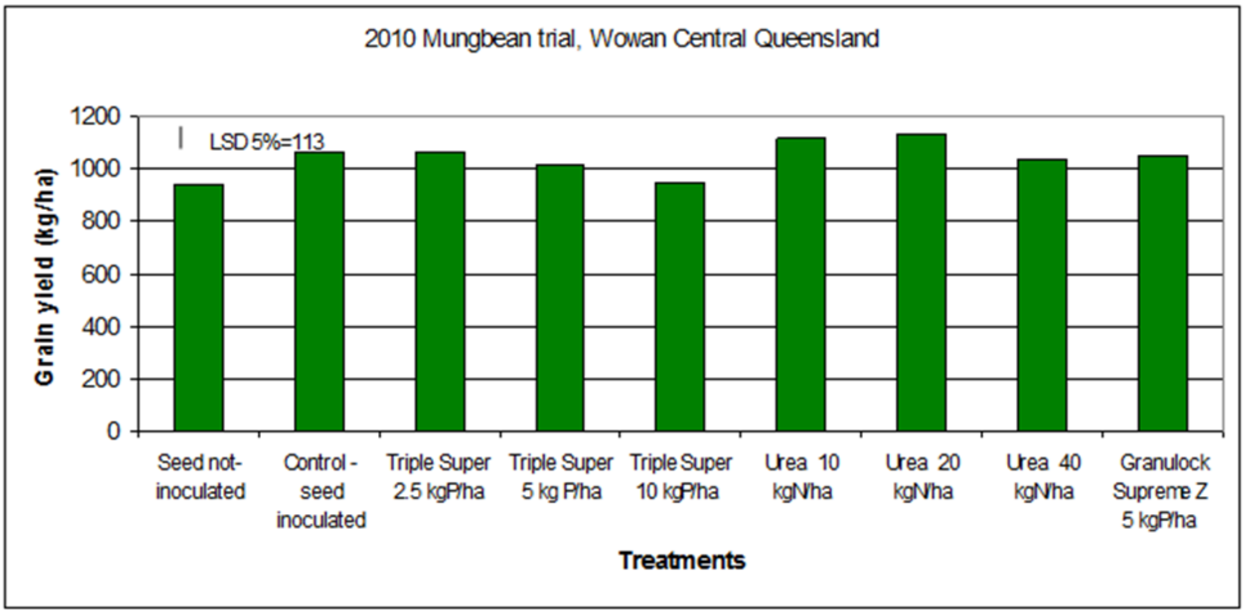


Figure 7. Response of mungbean cv. Crystal⊕ to inoculation and preplant fertiliser applications.

Summary

Nitrogen fixation in crops is closely linked to biomass production so agronomic practices that improve crop growth all lead to improved N fixation by the crop. Narrower row spacing for pulse crops has particularly shown to improve N fixation compared to wide (1.0m rows) at equivalent plant populations.

Sowing on time to take full advantage of soil water and growing conditions that maximise crop production can make a significant impact on amount of N fixed.

High soil nitrate levels can reduce legume nodulation and N fixation by rhizobia. The addition of N fertiliser does not give any yield advantage in pulses and may reduce the amount of N available for the following crop.

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. Many thanks also to all members of the GRDC Pulse Agronomy Initiative in Qld and NSW.

References

Seymour NP, Conway M, Erbacher A, Aisthorpe D and Quinlivan M (2011). Nitrogen fertiliser reduces nodulation of mungbean but gives no yield advantage in Central Queensland. 17th International Congress on Nitrogen Fixation. Fremantle, WA. 27 November -1 December 2011

Doughton JA, Vallis I, Saffigna PG (1993) Nitrogen fixation in Chickpea. I. Influence of Prior Cropping or Fallow, Nitrogen Fertilizer and Tillage. Australian Journal of Agricultural Research **44**: 1403 – 13.

Recommended reading

'Inoculating legumes: A practical guide.' Ground Cover Direct

https://grdc.com.au/~/media/Documents/Resources/Publications/GRDC-Booklet-Inoculating-Legumes.pdf

Managing legume and fertiliser N for northern grains cropping' Ground Cover Direct. www.grdc.com.au/GRDC-Booklet-ManagingFertiliserN

Contact details

Nikki Seymour
Department of Agriculture and Fisheries
Ph: 07 46398837
Fx: 07 46398800
Email: nikki.seymour@daf.qld.gov.au

Understanding & managing N loss pathways

Mike Bell, QAAFI, Graeme Schwenke, NSW DPI and David Lester, DAF Qld

Key words

Nitrate denitrification, ammonia volatilisation, N use efficiency, ^{15}N recovery, summer sorghum

NANORP codes

01202.027; 0102.004

Take home message

- Over the past 3 years, we have had 6 experiments with isotope-labelled (^{15}N) urea fertiliser in northern NSW and a further 11 in southern Qld, all focussed on measuring the fate of applied N fertiliser in summer sorghum. The use of ^{15}N allows us to trace the fate of urea-N applied to the soil from sowing through to harvest.
- Between 56 and 100% of the applied N was found in the soil and plant at harvest, with in-season rainfall (both timing and amount) and soil C and N status having a major impact on the seasonal loss potential.
- Avoiding unnecessarily high N rates, delaying or splitting N fertiliser so that peak N availability coincides with peak crop N demand, and relying on residual N from legume rotations all significantly reduced gaseous N losses from dryland sorghum, although the effectiveness of any management strategy varied with seasonal conditions.
- Nitrification inhibitor-coated urea significantly reduced nitrous oxide emissions in all studies, but did not improve grain yields enough to justify the additional cost on an agronomic basis.
- Depending on the season, delaying/splitting N applications gave either no yield benefit (dry season) or a significantly greater yield (good in-crop rainfall). Much of the unused N after a dry season remained in the soil and, provided loss events were not experienced during the fallow, significantly benefited the following crop.

Why the focus on N losses?

Fertiliser is a major contributor to crop variable costs, particularly in the northern parts of the region where soil organic matter and associated mineralisable N reserves continue to decline. This will continue to be the case unless the legume frequency in crop rotations increases substantially compared to that typically used (i.e. 1 legume crop in every 4-6 crops grown).

Given the substantial investment in N fertilisers, there needs to be considerable attention to factors that affect the efficiency of use of applied N (NUE), with indices such as crop recovery of applied N (kg fertiliser N accumulated in the crop or in the grain/kg N applied) and the agronomic efficiency of N use (kg additional grain produced/kg N applied) used to benchmark NUE. Any loss of applied N will affect NUE by reducing the pool of N that a crop can use to produce biomass and grain yield. Understanding the loss pathways and how they are influenced by seasonal conditions and management strategies are an important first step in optimising NUE for a given situation.

A recent survey of advisors throughout NSW and Qld (>150 advisors in total) showed the overwhelming majority recognized that N losses exist and can be significant, with a perception of increasing risks of losses in summer compared to winter cropping. There was also a perception of greater potential N losses (as much as 20-40% of applied N) in the northern part of the region, but given the unpredictability of environmental conditions that favour losses, few advisors actually factor those losses into fertiliser recommendations. The results from our projects conducted in the recently completed NANORP initiative, funded by GRDC and the Department of Agriculture) provide some interesting insights into these losses in summer sorghum cropping.

Where do losses occur, how big are they & what are the drivers?

Essentially, nitrogen can be lost from cropping soils via **downwards**, **sidewards** or **upwards** movement. **Downward** movement of nitrate [NO_3^-] via leaching is a greater problem in lighter textured soils than in the medium–heavy clays dominating the northern grains zone, but previous research has demonstrated some N losses, albeit small on an annual scale, can occur via this pathway.

Sideways movement can occur rapidly through erosion of organic matter rich topsoil during intense rainfall events, or more slowly through lateral subsoil movement of nitrate-N in soil water. The main **upwards** N loss pathways consist of gaseous losses through either ammonia volatilisation or denitrification of nitrate.

Ammonia volatilisation losses can occur soon after fertiliser is applied to soil, primarily when that fertiliser is surface applied. In previous research on northern NSW clay soils, we found losses from broadcast urea averaged 11% (5–19%) when applied to the surface of fallow paddocks, 5% (3–8%) when applied in a wheat crop (mostly dry soils), and 27% when applied to pasture. Ammonia N loss from pastures was higher as there was little rain after spreading. Nitrogen losses from ammonium sulfate were less than half the losses from urea at 2 pasture sites and 5 out of 8 fallow paddocks on non-calcareous soils, but were higher than urea (19–34% N loss) from fallowed soils containing more than 10% calcium carbonate (Schwenke 2014).

A range of factors influence the actual amount of N lost through ammonia volatilisation. Fillery and Khimashia (2015) recently published a simple model to predict ammonia volatilisation losses from fertiliser applied to moist soils. Their model starts with a maximum potential loss figure which is then discounted according to input factors including clay content, soil pH, fertiliser rate, rainfall in the week after application, presence of a crop canopy, and the placement of the fertiliser. Their model predicted the losses we measured in our fallow studies fairly accurately, but was not used on our studies in wheat paddocks where the potential for loss was deemed minimal due to the dry surface soil. In our field study we found that wind-speed after fertiliser application was also related to the amount of N lost over time.

Nitrate denitrification losses can be large, but require the simultaneous occurrence of low soil oxygen availability (an extreme example is when soil is waterlogged for an extended period), high soil nitrate concentration (soon after soils have been fertilized) and readily available (labile) carbon to support an active microbial community. Clearly, these set of circumstances do not coincide every year, but when they do, denitrification losses can be high, with rates of loss typically higher when soils are warmer in spring and summer rather than late autumn and winter. Interestingly, this is consistent with the survey information that the risk of N losses in the region was perceived to be greater in summer cropping and in the (warmer) northern cropping areas.

Unlike ammonia volatilisation, it is more difficult to quantify total N losses due to denitrification. This is because variable proportions of those losses can occur as N_2 or as N_2O, and direct measurement of denitrification losses in the field has so far only been able to quantify losses as N_2O. There are reports in the literature of the ratio of losses as N_2:N_2O being anything from 1:1 to 70:1, depending on soil and environmental conditions. To put this uncertainty into perspective, this means the our measurements of annual N_2O losses at fertiliser N rates delivering maximum yield of 1-2 kg N_2O-N/ha could be indicative of total denitrification losses ranging from negligible to >100 kg N/ha. The use of nitrogen fertilisers labelled with the ^{15}N isotope allows the fate of applied N to be studied in greater detail, with the difference between fertiliser N applied and that recovered in the plant (tops and roots) or remaining in the soil after harvest representing fertiliser N lost to the environment. In soils where fertiliser N has been banded below the soil surface and leaching losses are minimal (such as in the alkaline Vertosols), most of the unaccounted-for fertiliser N is presumed to have been lost via denitrification. When cumulative N_2O emissions data are available (such as in 12 of the 18

NANORP sites in Qld and NSW where ^{15}N was used), the ratio of total N lost (from ^{15}N results) to that lost as N_2O can be used to estimate the ratio of N_2 to N_2O for these summer cropping systems.

The impact of N source on loss susceptibility

Nitrogen for crop production can come from (a) soil organic matter, (b) crop residues—especially legumes, (c) manures, and (d) fertiliser. To minimise N losses, farm managers need to match zones and times of N supply with N demand (from crop production). Ideally, the N would be produced or added as the crop needs it, but it must also be available where the plant roots can access it, i.e. in soil with available moisture for active roots.

Mineralisation of organic matter, residues and manures to plant available N forms requires moist soil and warm temperatures, so rates of N produced are greater during summer than winter. How much mineral N much is produced depends on the amount of organic matter in the soil, the amount of crop residues remaining and their N concentration, and the amount and type of manure applied, its N concentration and its method of application. In contrast, fertiliser N is either immediately available for plant use (in ammonium or nitrate forms) or soon available after conversion in soil (e.g. from urea to ammonium and nitrate).

Under non-waterlogging conditions nitrate [NO_3^-] is the N form that is produced in the soil regardless of the original source, and will accumulate over time if no significant N losses occur. So, the principal impact of N source is in the timing and rate of mineral N accumulation in the soil. If a loss event occurs while mineral N is still being produced, only that already present as nitrate will be subject to loss. If a loss event occurs after all mineralisation or urea conversion through to nitrate has taken place, then the original source will have little influence on how much is lost. An advantage of mineralisation-sourced N is that its slower-release may see it progressively distributed throughout the soil profile by fallow rainfall, rather than being present in a concentrated zone if applied all at once from fertiliser.

Managing N losses from any of these sources requires matching the times-of-year the N becomes available with potential for intense rainfall events and the time-of-year that the N will be required by the crop. Since applying N fertiliser at sowing creates a pool of nitrate N in the soil that is largely not accessed by the crop during the first 2 months post-sowing, this nitrate is at risk of denitrification losses. In splitting N application between sowing and booting, we have demonstrated reductions of 58–81% in N_2O emitted (largely from denitrification), compared to urea all-at-sowing. In a dry growing season, the late-applied N may not have sufficient rainfall to enable its uptake for crop production, as we found in 2013-2014 sorghum season. However, in situations where there are no major loss events between one crop season and the next, this unused N may be available to the following crop in the rotation sequence. An example of this is discussed for unused fertiliser N from a split N application in NSW in 2013/14 season.

Use of urease & nitrification inhibitors to limit fertiliser N losses

Urease is a naturally occurring enzyme that increases the rate of conversion [hydrolysis] of urea [$CO(NH_2)_2$] to ammonium [NH_4^+]. Urease inhibitors are applied with urea to delay this conversion and keep the urea in the urea form. When hydrolysis occurs it creates a localised zone of highly alkaline pH which further converts some of the ammonium to the gaseous form ammonia [NH_3], which can be lost from the soil surface by volatilisation. The greatest risk of volatilisation loss occurs when urea is broadcast onto a moist soil surface and is not incorporated into the soil via rainfall or machinery. While there are many compounds that can inhibit the urease enzyme, the main one available for use in Australian agriculture is NBPT [N-(n-butyl) thiophosphoric triamide], although it is actually the breakdown product of NBPT that is the inhibitor. Urea coated with NBPT has been shown to reduce ammonia volatilisation loss in a range of crop and pasture situations.

Nitrification is the process of conversion of ammonium [NH_4^+] to nitrate [NO_3^-] in the soil, so the use of a nitrification inhibitor with an applied fertiliser aims to delay this process and keep more of the nitrogen in the ammonium form. The reason for applying this inhibitor is to prevent N loss via nitrate leaching or nitrate denitrification, which occurs in anaerobic soil conditions (e.g. waterlogging). Losses from denitrification in dryland cropping are sporadic, but can result in up to 50% of the applied fertiliser N being lost to the atmosphere, mainly as di-nitrogen gas [N_2]. The greenhouse gas nitrous oxide [N_2O] is also emitted from the soil during denitrification. Unlike ammonia volatilisation, which only occurs at the surface, denitrification occurs within the soil wherever nitrate and labile carbon are present (the carbon is an energy source for the microbes which drive this process). Denitrification gases [N_2, N_2O] are not retained by soil adsorption, whereas ammonia [NH_3] is easily adsorbed by soil surfaces. Some of the chemicals that can be used to inhibit nitrification include 3,4-dimethylpyrazole phosphate (DMPP), dicyandiamide (DCD), and 2-chloro-6-(trichloromethyl) pyridine. Urea coated with DMPP (commercially available as Entec®) has been shown in 4 northern NSW and 4 Qld trials to reduce N_2O emissions by an average of 85% (range: 65–97%) compared to uncoated urea. Despite the reductions in N_2O loss, there have generally been marginal or no benefits to grain production or gross margins from using DMPP that justified its additional cost compared to untreated urea.

Measurement of fertiliser N losses with ^{15}N-isotope-labelling experiments (2012-2015)

During the past 3 years we have used isotope-labelled (^{15}N) urea fertiliser to trace the fate of applied N in 6 season-long mini-plot field experiments with sorghum near Tamworth and Quirindi/Breeza in NSW, and in 11 experiments on the Darling Downs and Inland Burnett regions in Qld (Kingsthorpe, Kingaroy, Kupunn, Bongeen and Irongate). Normal fertiliser contains ^{14}N so the use of ^{15}N allows us to trace the urea-N applied into the harvested grain, the plant residues, large roots, and the soil profile after harvest. The difference between what we applied and the total of what was found after harvest was assumed to be the N lost by denitrification, as the urea was mixed/banded into the soil to minimise ammonia volatilisation, adjacent crop rows and soil were sampled to quantify any lateral movement and/or the mini-plots had raised steel borders to minimise surface runoff. Possible leaching of applied N was accounted for by deep coring of the mini-plots and measurement of mineral N to 150 cm depth. As ^{15}N fertiliser is extremely expensive, all measurements were confined to small mini-plots (1 m2) within larger field trials.

Trial results

NSW sites (see Figure 1).

In **2012-13** experiments, total gaseous loss (N_2 + N_2O) ranged from 28–45% of applied N. At the Tamworth (drier) site, there was no effect of N fertiliser rate on the proportion lost (21%), while at the Quirindi (wetter) site, N losses were 43%, 44% and 27% from the 40, 120 and 200 kg N/ha treatments, respectively. It is likely that the proportion lost from the 200 N rate was lower because some of the excess nitrate N moved down in the soil during the heavy rainfall period rather than being denitrified. Evidence for this was seen in the greater uptake of applied N into the grain protein in this treatment.

In **2013-14**, a much drier sorghum-growing season, we used ^{15}N either as (a) urea at sowing, (b) as urea applied at 7-leaf stage, or (c) as urea applied at sowing with a nitrification inhibitor (DMPP). At the Tamworth site, there was no difference in total N lost between treatments (26%), but of the N applied only 10% was found in plant tissue at harvest when applied at the 7-leaf stage, compared to an average of 36% in the plant when N was applied at sowing. This is because there was only one rainfall event after the late-applied N fertiliser, so limited opportunity for plant N uptake after the topdressing. At the Quirindi site, there was only 4% total N loss from the inhibitor treatment, compared to an average N loss of 20% from urea either applied at sowing or at 7-leaf stage. The main difference between the urea and the inhibitor treatment was in the extra 15% of applied N found in the soil at harvest in the treatment where the inhibitor had been used, compared to ordinary urea. Only 13% of the late-applied N was found in the plant tissue (including grain) at harvest, compared to an average of 28% in the other treatments applied at sowing.

In **2014-15**, an ideal summer for sorghum growing (after a dry start), our treatments compared (a) urea added at sowing, and (b) urea split between sowing (33%) and 7-leaf stage topdressing (67%). At the Tamworth site, there were also two different N rates applied, depending on whether the previous crop was sorghum (120 kg N/ha) or soybean (40 kg N/ha).

Overall N losses averaged 29%, and were not affected by the previous crop, but were 4% greater when the N was applied all-at-sowing. The difference in N loss was an extra 4% found in the top 0-10 cm of the soil of the split N treatments; there was no difference in N recovery in the crop.

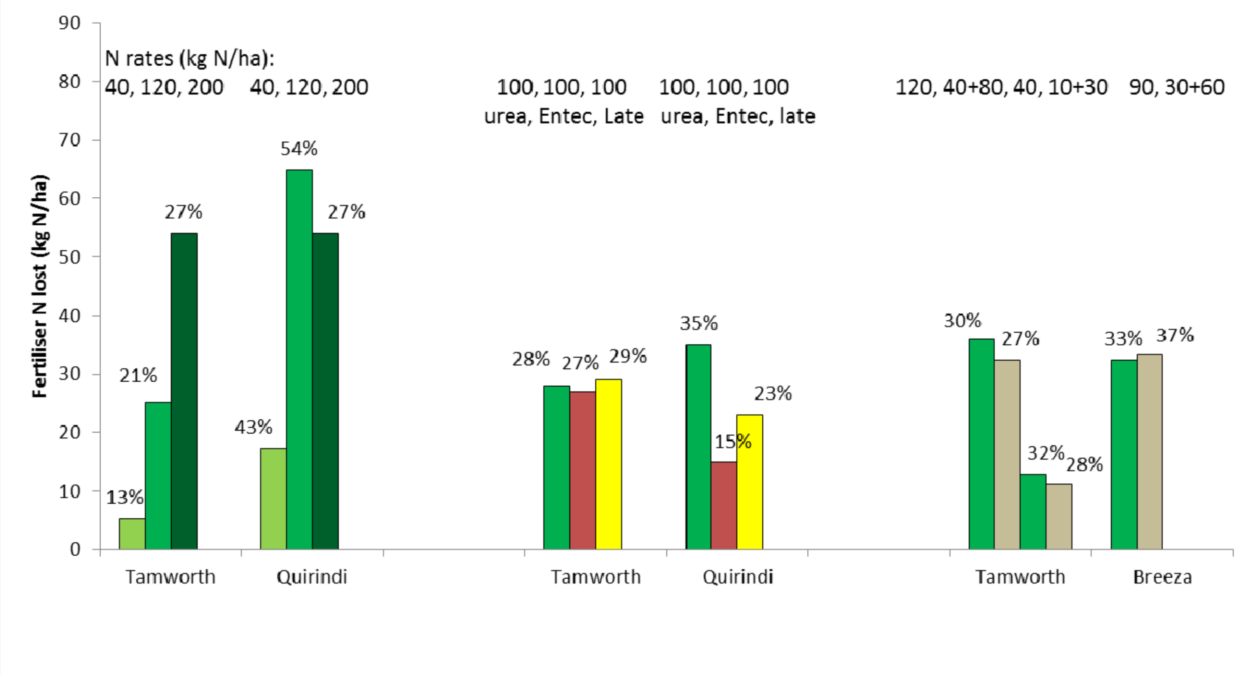


Figure 1. Losses of applied urea-N in field trials on Vertosol soils in northern NSW during the NANORP project. Losses were calculated from recoveries of 15N labelled urea in soil and plant material.

Qld sites (see Figure 2).

In a very wet 2012-13 season, total gaseous loss (N_2 + N_2O) ranged from 23–48% of N applied prior to or at sowing on black and grey Vertosols but was minimal with split applications on a brown Ferrosol near Kingaroy with very low soil N reserves. On the Vertosol sites at Kupunn (sown early October) and Kingsthorpe (sown late November) losses tended to increase with fertiliser N rate, representing 23%, 40% and 47% at Kupunn and 34%, 46% and 48% at Kingsthorpe for the 40, 80 and 120 kg N/ha rates, respectively. The high losses in the 80 and 160 kg N/ha rates at Kupunn emphasised the vulnerability of any excess fertiliser N supply (optimum N rate was 80N at that site) remaining in the soil during a late season wet event (block received 100mm and was flooded near physiological maturity). Conversely, the N_2O-N emissions monitored at Kingsthorpe suggested most losses occurred in response to prolonged wet (not waterlogged) soil in the 6-8 week period following sowing and fertiliser application (i.e. before most crop N uptake occurred). For this site-season combination the optimum N rate was ~170 kg N/ha.

At the Kingaroy site the interaction between rotation history (grass or legume ley pastures) and N rate was explored, with the higher fertiliser N requirement after the grass ley (100 kg N/ha versus 70 kg N/ha after the legume ley) resulting in similar crop yields but emissions intensities (kg N_2O-N/t grain yield) twice as high as in the legume history.

The **2013-14** season was much drier, as in NSW. Experiments again looked at losses in response to urea-N rate (Bongeen), while also comparing responses to urea to those from urea with a nitrification inhibitor (Kingaroy and Kingsthorpe). The impact of the inhibitor was assessed in terms of crop performance (growth, yield and N uptake), but total gaseous N losses determined using ^{15}N were only assessed for the urea treatments. Losses were lower at all the Vertosol sites (13-30% of applied urea-N), but slightly higher in the Kingaroy site (15-25% of applied N), with the latter requiring frequent sprinkler irrigations (totalling 160mm) to provide enough water to grow the crop. The relationship between losses and N rate evident in 2012/13 was not as consistent in 2013/14, and was perhaps most evident at the irrigated Kingaroy site, where 14%, 18% and 28% of applied N was lost in the 40, 80 and 120N rates, respectively (optimum N rate at this site was ~120 kg N/ha). In the Vertosol sites the lower yields and crop demands (and hence lower optimum N rates) did not lead to large N losses during the growing season as there were few (2 at Kingsthorpe and only one, near physiological maturity, at Bongeen) significant rainfall events and most 'surplus' fertiliser N could be found as NO_3-N in the soil profile after crop harvest.

Despite 65-70% reduction in annual N_2O emissions in the treatments with the nitrification inhibitor at both sites, there was little agronomic benefit other than a slight (10-15 kg N/ha) reduction in the optimum N rate and a slight increase in yield (the latter at Kingaroy only) with the inhibitor. These responses were not sufficient to cover the price premium charged for the commercial nitrification inhibitor product (i.e. ~20% more/kg N applied).

2014-15 turned out to be a great sorghum growing season after a dry start that caused poor crop establishment and a replant at one early-sown trial site. We ran 5 experiments, with 3 again comparing rates of urea with urea and a nitrification inhibitor. The other sites either simply looked at urea N rate (Irongate early sown) or the interaction between N rates and crop rotation history (Kingaroy). In the later sown Vertosol sites that experienced wet conditions during early growth (Irongate late and Kingsthorpe) losses again increased with N rate, although not always as a proportion of N applied. Losses ranged from 15-45% of applied N, depending on site, with the contrast between the early and late sown Irongate sites particularly interesting. Fertiliser N was applied at the same time at both sites (planting of the successful early sown block), but there was no effective rainfall after that until flowering in the early block (and re-sowing of the late block). The lower losses of fertiliser N in the early sown block were related to the strong sink present (a well grown sorghum crop near flowering) when the fertiliser N was converted to nitrate-N by in-season rainfall, compared to the late sown block where nitrate rapidly became available but there was effectively no crop uptake for a period of 4-6 weeks, during which soils remained wet.

Once again, the reduction in N_2O emissions from use of the nitrification inhibitor was much greater than any effect on crop growth or fertiliser N requirement. The effect of grain legumes in the crop rotation on fertiliser N requirement, N_2O emissions and N losses was also consistent with the ley pasture trial in 2012/13 – fertiliser N requirements were less and N_2O emissions intensity was lower (by 25%) in the legume systems compared to back to back sorghum.

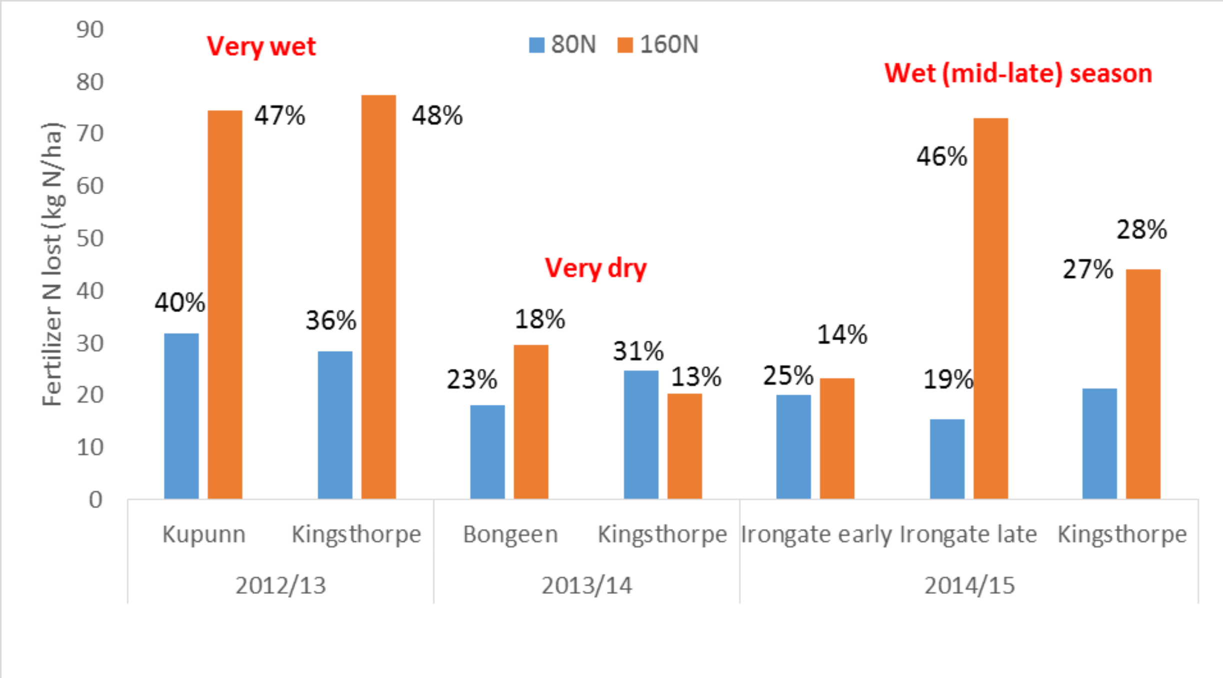


Figure 2. Losses of applied urea-N in field trials on Vertosol soils in Queensland during the NANORP project. Losses were calculated from recoveries of ^{15}N labelled urea in either soil or plant material.

Local case studies illustrating management strategies to reduce N losses

NSW – Impact of timing of N application (Courtesy of Maurie Street and Ben O'Brien, GOA)

In 2015, two central-west wheat trials on nitrogen rate and timing of application showed poor crop N uptake by wheat when urea was pre-applied in late December 2014. At both sites (Narromine, Nyngan), the urea was drilled into sandy clay loam topsoils. The sites had already had 40-50 mm during December and another 30-40 mm followed in the week after N was applied. Another 140-180 mm of rain fell from January until sowing in early May 2015. The aim of these trials was to compare pre-applied N, at-sowing N and in-crop N applications on wheat production and grain protein. While the crop data is not yet available, in-crop sensing results (NDVI) indicated that the pre-applied N treatments were not showing the N-rate responses seen in the at-sowing N treatments.

Pre-sowing soil testing conducted in the pre-applied N plots was unable to account for 2–91% of the N applied in December, with greatest apparent losses in the 200 kg N/ha treatments at both sites. Profile results indicated little or no downward movement of mineral N below 30 cm depth in the soil. Nitrate denitrification was presumed to have caused much of these losses since the urea was incorporated into the soil. However, some ammonia may have volatilised from the soil surface of these light-textured soils. Weed N uptake and N immobilised by microbial breakdown of crop residues may also have accounted for some of the applied N.

Qld – Impact of legume N on fertiliser requirement and N_2O emissions

An experiment was established at Kingaroy to explore the impact of crop rotation (grain or grain legume pre-histories) on fertiliser N requirement and NUE during a subsequent sorghum crop in 2014/15. The pre-histories were sorghum, peanut or soybean in the 2013/14 summer, all harvested for grain. In the second summer crop year (sorghum), the fertiliser N rate required to achieve maximum sorghum grain yield (6.3 t/ha) was reduced by at least 50% after a peanut rotation (i.e. 60 kg N/ha compared to 120 kg N/ha) or eliminated totally after a soybean crop (i.e. no fertiliser N response). Fertiliser N losses determined using ^{15}N recovery were negligible at the optimum N rate in each history (<5 kg N/ha), with 65-70% of the applied N accumulated in crop biomass at this high yielding site. Regardless, cumulative N_2O emissions during the growing season and the emissions intensity (kg N_2O N/t grain produced) were 35% higher in the sorghum history with 120 kg N fertiliser/ha than in legume histories with 60 kg N fertiliser/ha.

Acknowledgements

This research was funded by the Australian Government Department of Agriculture, as part of the National Agricultural Nitrous Oxide Research Program (NANORP). However it was made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, and the authors would like to thank them for their continued support. In NSW, we gratefully thank Ian Carter for the use of “Connemara” and “Romney Vale” on the Liverpool Plains. Other trials were located on NSW DPI Research Stations near Tamworth and Breeza. In Qld we would like to thank Warakiri Ag Trust Manager Scott Reichelt, Andrew Ruhl and Peter Bach for the use of ‘Myola’, ‘Seacres’ and ‘Craigielee’, with other trials located on the DAF Research Stations at Kingsthorpe and Kingaroy.

Many people assisted with various aspects of field operations, sample processing and sample analyses. In NSW this included Matthew Gardner, Rick Graham, Peter Formann, Mustafa Kamal Hossain, William Keene, Kelly Leedham, Annabelle McPherson, Adam Perfrement, Peter Sanson, Zara Temple-Smith, Wayne McPherson, Guy McMullen, and Loretta Serafin (NSW DPI, Tamworth), while Leanne Lisle (UNE), Brad Keen, Stephen Kimber and co-workers (NSW DPI, Wollongbar) conducted various analyses.

In Qld the project team also included Prof Peter Grace, Dr Clemens Scheer, Dr David Rowlings and Dr Max de Antoni Migliorati (QUT), while the field program was managed by Gary Harch, Peter Want, Lawrie Smith, Peter Aegis, Rod Obel and Trish Balzer. Julie Renwick, Alice Strazzabosco, Rachael Nicholls and John Taylor (QUT) are recognized for their analytical work.

References

Fillery IRP, Khimashia N (2015) Procedure to estimate ammonia loss after N fertiliser application to moist soil. Soil Research (online early) http://dx.doi.org/10.1071/SR14073

Schwenke G (2014) Nitrogen volatilisation: Factors affecting how much is lost and how much is left over time. http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Factors-affecting-how-much-N-is-lost-and-how-much-is-left-over-time

Contact details

Mike Bell
University of Queensland
Gatton Campus, Gatton 4343
Ph: 07 5460 1140
Email: m.bell4@uq.edu.au

Graeme Schwenke
NSW DPI
4 Marsden Park Road, Tamworth
Ph: 02 6763 1137
Email: graeme.schwenke@dpi.nsw.gov.au

David Lester
DAF Qld
Leslie Research Centre, Toowoomba 4350
Ph: 07 4639 8886
Email: david.lester@daf.qld.gov.au

Part I: Super cool results – achieving great aeration results and Part II: Silo recirculation as an aid to fumigation

Philip Burrill, DAF Qld.

Key words

Grain aeration, grain temperature, grain quality, storage pests, aeration fans, fumigation recirculation

GRDC code

PRB00001

Take home message

- Seek advice to ensure the right size aeration fans and associated equipment are fitted – ducting, roof vents and fan controller. Not all silo suppliers get it right.
- Recommended aeration cooling airflow rates are 2 to 4 litres of air per second, per tonne (L/s/t). Do your aeration fans achieve this when your silos are full of wheat, barley, chickpeas, sorghum, canola?
- Are you achieving the target 'grain temperatures' of 18° to 23°C during summer storage and less than 15°C during the winter period?
- Aeration maintenance: farm case studies show that aeration equipment checks and maintenance can lead to a significant improvement to aeration performance and grain storage results.
- Recirculate air with a small fan during fumigation in a sealed silo (150 – 2000 tonnes) ensures rapid, uniform distributes of phosphine gas. Otherwise it can take 2 – 5 days for gas to reach all areas inside a silo.

Storage best practice – four key steps

Aeration cooling is just one of four key best practice strategies that provide good results for on farm storage. When combined, they form the foundation for successful storage and importantly, a grower can build a reputation as a reliable supplier of quality grain.

1. Aeration: correctly designed and managed, will provide cool grain temperatures and uniform grain moisture conditions. The result is reduced problems with grain moulds and insect pests in storage, plus the ability to maintain grain quality attributes such as germination, pulse seed colour, oil quality and flour quality.
2. Hygiene: a good standard of storage facility hygiene is crucial in keeping storage pest numbers to a minimum and reducing the risk of grain contamination.
3. Monitoring: monthly checking of grain in storage for insect pests (sieving / trapping) and at the same time inspect grain quality and temperature. Keep a monthly storage record to record these details, including any grain treatments you applied.
4. Fumigation: in Australia we now only have gases (fumigation) to deal with insect pest infestations in stored grain. To achieve effective fumigations the storage/silo must be sealable – gas-tight (AS2628) to hold the gas concentration for the required time.

Effective aeration – what does it look like?

For the summer storage period November to April we aim to achieve grain temperatures of 18° to 23°C with well managed aeration cooling. For the winter period May to September the target is grain temperatures of less than 15°C.

Push a robust thermometer attached securely to a broom handle, or better, a purpose built grain temperature probe one meter into grain. Leave for a few minutes in grain before reading to see what grain temperature your aeration system has achieved.

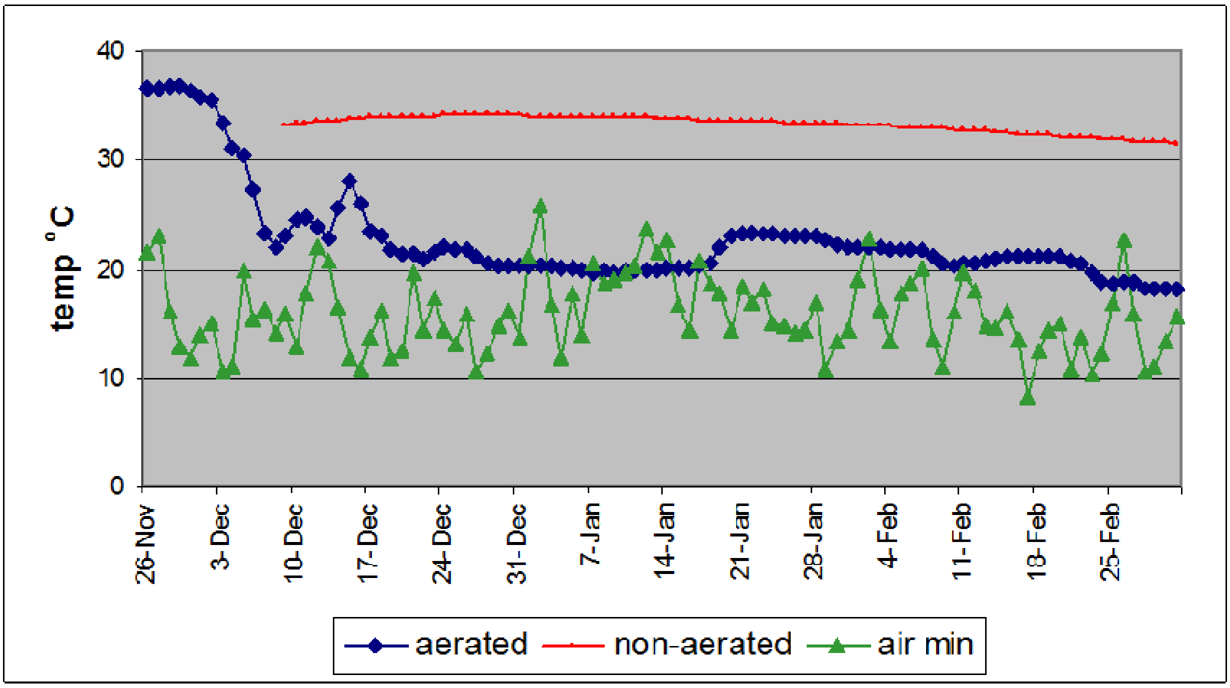


Figure 1. Two silos -wheat. Non-aerated silo had grain temperature sit above 30°C for 3 months, ideal for insect breeding. Well managed aeration in summer brings temperatures down towards 20°C.

Aeration - achieving good results

There are three areas to focus on for good aeration results:

a. Aeration equipment for the job

b. Operating aeration system effectively

c. Maintaining / checking the equipment is doing the job

a. Aeration equipment for the job

The three main components are fans, ducting inside the storage and the roof vents.

Fan selection: Fan size, number per silo and type of fan are common areas for confusion. It usually requires an "experienced grain aeration specialist" to provide advice to either the silo manufacturer / supplier, or directly to the grower. There are a number of important considerations to consider before fitting fans to a silo or storage.

Silo size - height & width, electricity supply available at site, grain types stored, typical harvest grain moisture contents, and what is the intended purpose of fans? Is it only for aeration cooling (2 - 4 L/s/t) , or do you want to set up one or two silos with much larger airflows (15 - 25 L/s/t) for the purpose of aeration drying?

These details can be quickly sorted out with one or two phone calls, when you are dealing with an experienced aeration specialist. It is vital that the right questions are asked. The result, the fan selection, ducting and venting design suits the intended purpose for your grain storage situation.

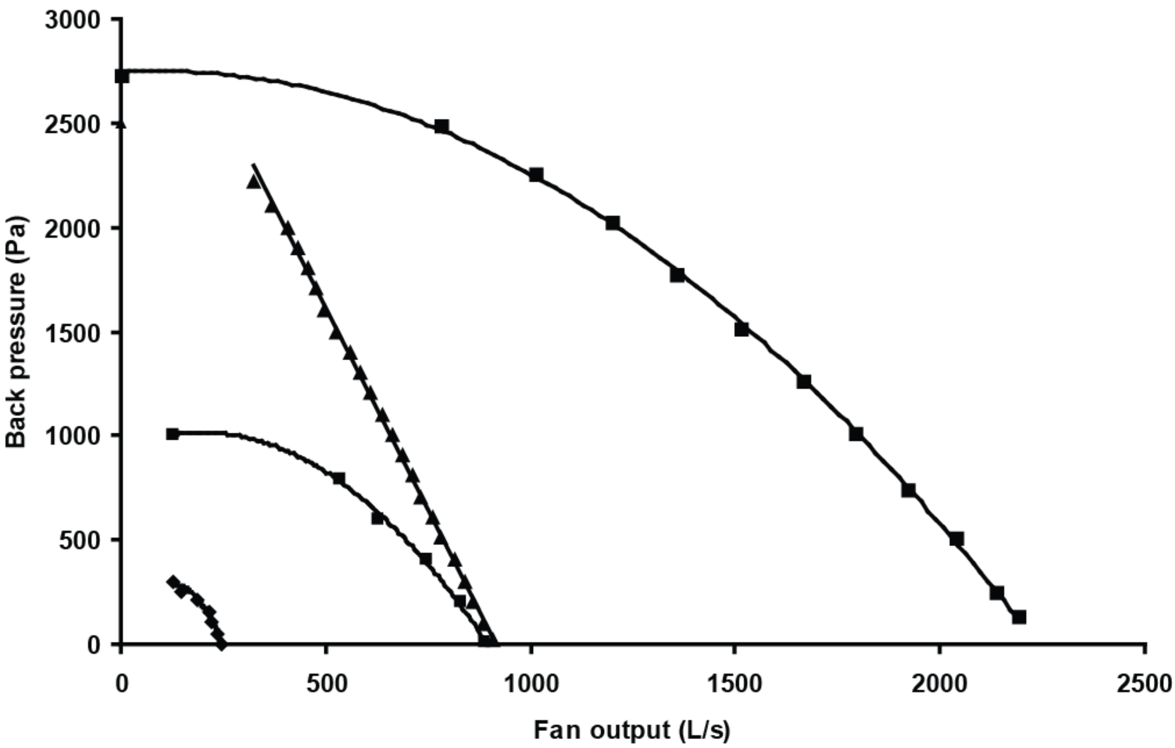


Figure 2. Note the large variation in aeration fan ouputs for four typical fans fitted to grain storages

Farm case study 1: A 130 tonne capacity cone based silo, nearly full with 105 tonnes of barley, fitted with one 0.37 kW aeration fan was tested for airflow output. Using the 'A-Flow' testing device (GRDC fact sheet, "Performance testing aeration systems") the single aeration fan was only able to generate 166 litres of air per second, or 1.6 L/s/t airflow against the 105 tonnes barley. Result: grower decided to fit a second fan (same size) on the opposite side, aiming for 3.0 L/s/t

Farm case study 2: Two Grainmaster™ 150 tonne capacity cone based silos, both fitted with a pair of 0.37 kW Agrdry F100 aeration fans. One silo was full with 140 tonnes of Soybeans and the other silo full with 150 tonnes of White French millet. With identical fans running on identical silos the total airflow output through the soybeans was 397 L/s, providing a useful 2.8 L/s/t. However airflow going into the White French millet silo was only a total of 141 L/s, providing a much lower 0.9 L/s/t. The extra back pressure on fans created by the small seed millet was reducing aeration airflow to well below the recommended cooling range of 2 – 4 L/s/t.

Ducting inside silo: There are two common types, the round tube ducting that can be made to lift up for cleaning, or the house shaped ducting that is fixed down to the cone base. Ducting length, strength, location in silo and size of perforation holes / slots, are all involved in achieving optimum airflows through grain. Ability to clean and remove grain residues from ducting for silo hygiene is important for both cone base or flat bottom silos.

Roof vents: Vents can be as simple as a "Chinaman hat style" used on the centre fill top hatch, or the many variations of "goose neck" roof vents. Unfortunately it is not uncommon to see venting design problems on range of silo brands.

The vent size / area needs to be appropriate to suit the fan output. A fan's airflow should not be used at start up to lift heavy vent lids, or constantly work against lid springs. This ensures fan airflow is not restricted. For all sealable silos, vents require simple, effective systems for creating a gas tight seal during fumigation. Do you also have easy access to vents for maintenance on rubber seal?

Farm case study 3: Three new 150 tonne capacity, sealable, aerated silos, each fitted with two 0.37 kW Downfield F370 aeration fans (smallest curve on Fig. 2 is the F370 fan). The storage facility manager was concerned about fan output after he tested fans shortly after the silos construction was completed. He was comparing the operating sound of fans running using the four vents fitted to the roof, with the fan's sound when he also manually opened the centre top fill hatch as well. The fan performance sounded like it improved with the extra vent space provided.

When fan output was tested (A-Flow device) on the 'empty' (no grain back pressure) new silo, the pair of F370 fans could only achieve a total of 209 L/s airflow with the four vents used as designed. When the centre top fill lid was also opened, output immediately increased to 517 L/s.

On closer inspection the 4 sealable vents on the roof had no system to hold them open during aeration. There was only a long flexible cable to pull them closed / sealed for silo fumigations. Fans were losing more than half their unloaded performance, just by forcing them to lift four steel plate vent lids. Result: when the silo manufacturer was made aware of the design problem they arranged to fit a simple vent lid lifter.

Access to four vents around the roof edge to maintain rubber seals, is the next design challenge.

b. Operating aeration system effectively

Running the fan at the right times will achieve cool grain temperatures and uniform moistures. Aeration cooling aims to push through a series of 'cooling fronts' starting from the base of the silo.

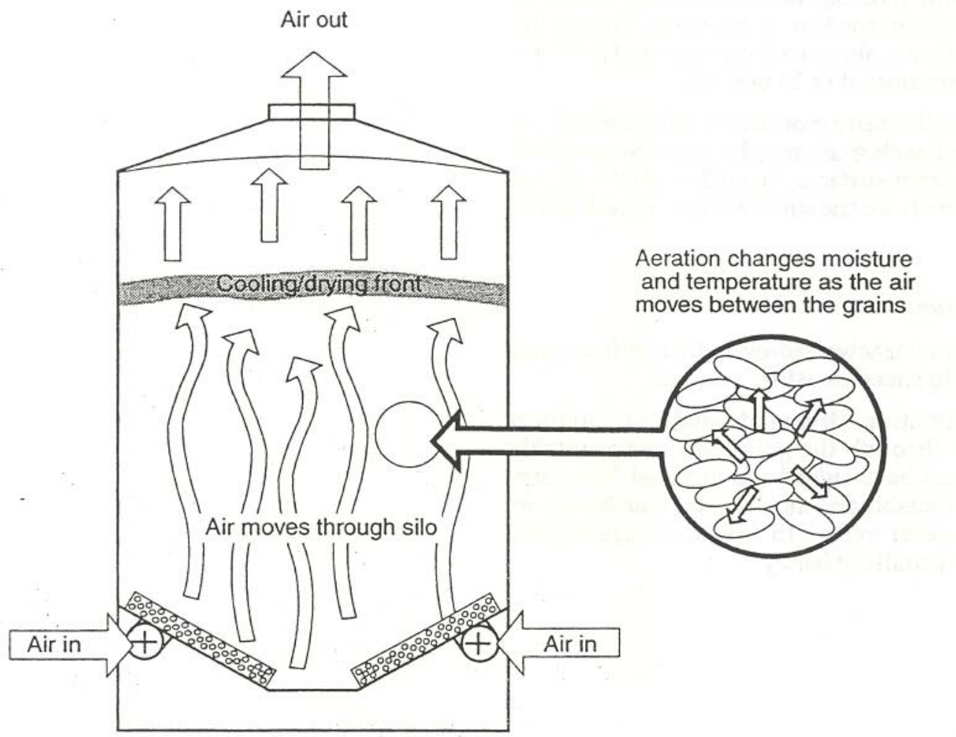


Figure 3. Cooling / drying fronts in the aeration process (C. Newman Agric. WA).

While there are a number of producers still manually operating aeration fans, for most storage facilities we recommend using a good quality automatic aeration controller with a sensor measuring both ambient air temperature and humidity to automatically turn on fans at optimum times.

<u>Manual operation of fans</u>

There are three stages when operating aeration cooling fans from the start of harvest:

1. As soon as enough grain covers the ducting, turn on aeration fans while filling silo. Run continuously (24hrs / day) until the first cooling front comes through the full grain depth. This usually takes 3 - 5 days. If safe, go to the top of the silo and see if the air coming out has changed from a warm, humid smell to a fresh, cool smell. The first cooling front is through. See Fig 3.
2. Once this has occurred, run the fans for approximately 12 hours per day for the next 5 – 7 days. Select the cooler night air, but avoid extended periods of high humidity air which may wet grain. Avoid fog, misty or showery conditions.
3. Check the grain temperature and condition. Grain temperature in summer should now be close to 20°C. The longer term “protect” phase now begins. Operate fan for approx. 100 hours per month, selecting cool, mostly dry air from 3 - 5 days per week to maintain cool grain conditions. An automatic controller will usually be much more reliable at this task.

<u>Automatic controller operation of fans</u>

Today there are automatic aeration controllers available that automatically step through the three stages outlined above.
Seek independent advice as to what are the better quality controllers to consider, as there are poor quality units that may put your stored grain at risk. Ensure the supplier has a good reputation for providing after sales support and parts if required.
For a new unit fitted to a storage facility, there is simple start up process to follow. See manual, or consult supplier. As a general rule, leave the auto controller itself powered up. It is recording a history of current weather conditions so it is able to turn fans on at the optimum times.

c. Maintaining and checking aeration equipment

There are a few basic checks and maintenance steps to ensure your system is doing the job.

1. Check grain temperatures to see if you are achieving the target temperatures of 18° to 23°C during summer storage and less than 15°C during the winter period.
2. See Fig. 4 where an OPI® cable was used in the aerated barley silo (“Farm case study 1”) to record grain temperatures at various depths. This helped identify the low airflow problem.
3. When checking silos each month for insects, also look at the hour meter on the aeration auto controller to see if fans are averaging approx. 100 hours per month (+/- 20 hrs).
4. At least once per year use a good quality thermometer and relative humidity reader to check the aeration auto controller’s sensor has not been damaged and is readings correctly.
5. Manually test-run fans on silos to check they are all operating. Clean fans if required.

Farm case study 4: A ten minute fan cleaning job can produce large improvements**.** A single 0.37 kW aeration fan was tested for airflow output on a 128 tonne capacity coned based silo holding 105 tonnes of barley. It was observed that the fan impeller had a significant build-up of dust on the blades prior to testing. Using the ‘A-Flow’ testing device, the aeration fan output was recorded as 86 L/s, or 0.8 L/s/t airflow against the 105 tonnes barley. After cleaning the dust from the blades the fan was retested and produced an output of 152 L/s, or 1.5 L/s/t. Result: grower cleaned remaining fans.

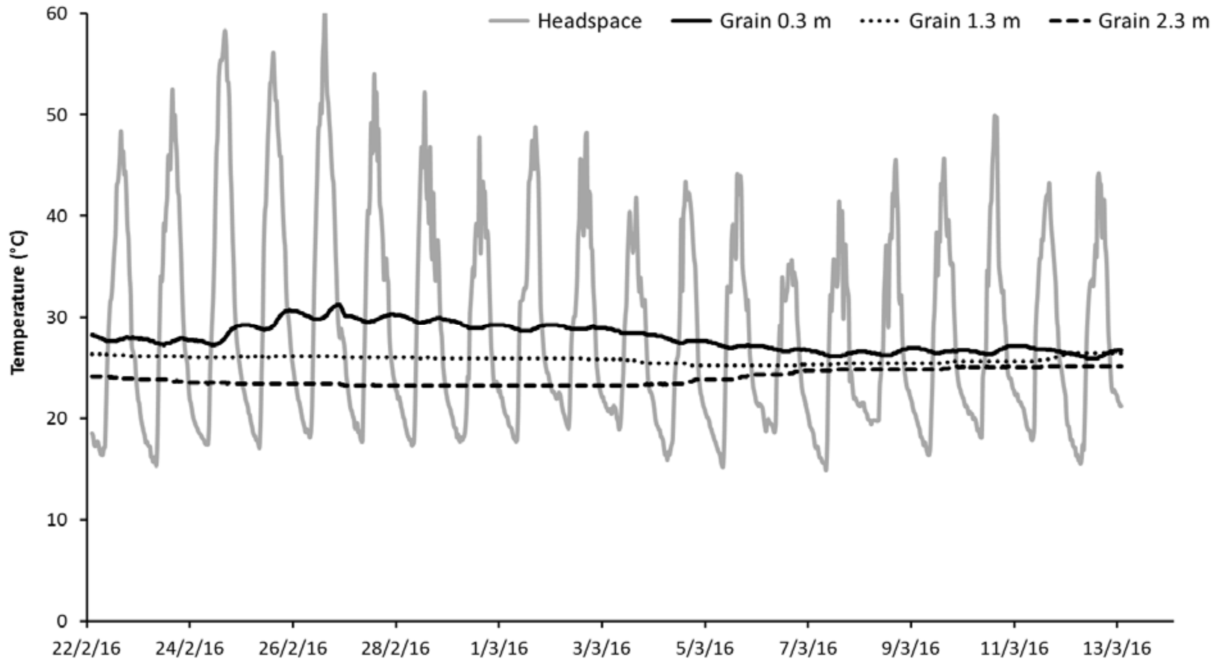


Figure 4. Temperatures in a silo of barley, in headspace and at three grain depths. The warmer than expected grain temperatures indicated possible aeration problems. See Farm Case study 1.

Silo Recirculation – how can it help with fumigation?

Australia now only has gases to control live insect pests in infested grain. Dichlorvos spray on insecticide is no longer registered for this use. To achieve effective fumigations, silos must be pressure tested to check they are sealed – gas-tight. This ensures they hold high gas concentrations for the required time to kill pests.

Silos pressure tests can be carried out by using a short burst (5 – 10 sec.) of the aeration fan, or a portable leaf blower to initially pressurise the silo for the test. The pressure decay (250 to 125 Pa) can timed by using the silo's relief valves, a length of 20 mm clear plastic tube in a "U" shape with water in it (manometer), or a digital manometer connected to the silo. See GRDC Fact Sheet : "Pressure testing sealable silos". http://storedgrain.com.au/pressure-testing/

During fumigation, phosphine gas is typically liberated over 5 or 6 days from the tablets or blankets that have been placed in the silo. This gas however only moves slowly, taking about 24 hours to travel 6 meters through grain.

If you are fumigating a medium to large silo (150 – 2000 tonne silo) the gas may take 2 – 5 days to eventually arrive in all parts of the silo. In large silo fumigations this may result in some grain, at the furthest distance from tablets, only getting 6 days of phosphine gas instead of the required 10 days or longer exposure period. Six days is not enough time to kill all the life cycle stages of the pests.

A typical phosphine fumigation required to kill all pests is a minimum of 200 ppm phosphine gas concentration for at least 10 days. See horizontal blue line in Figure 5 below.

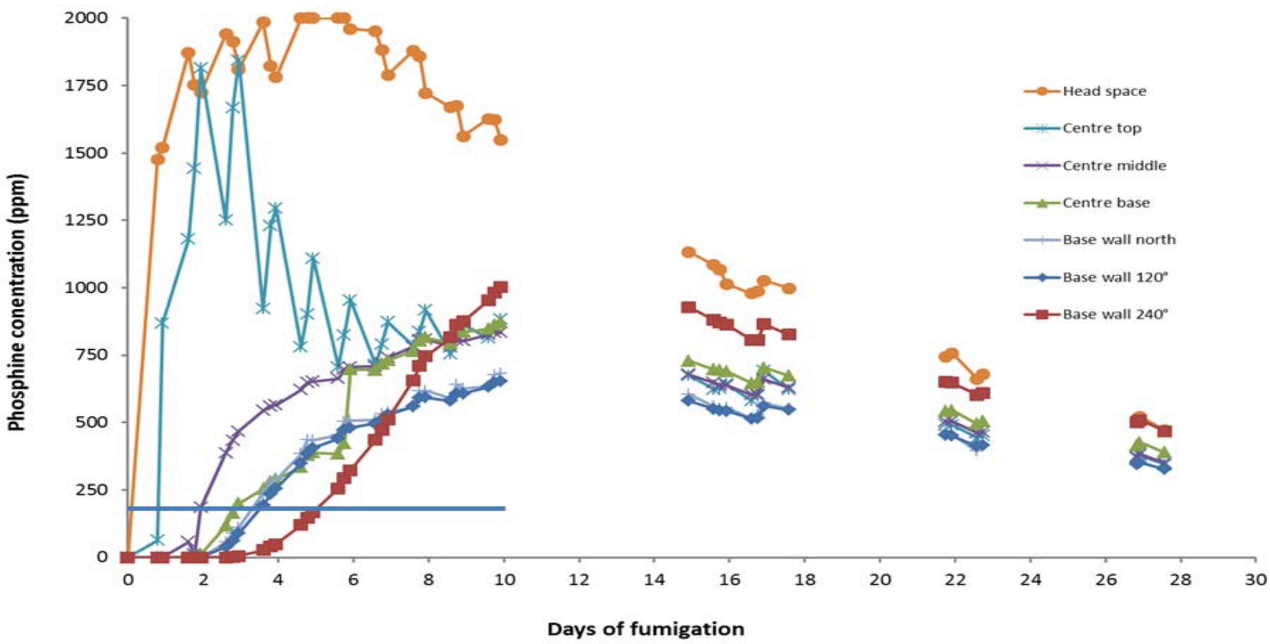


Figure 5. Phosphine gas concentrations at 7 points in a silo during fumigation of 1416 tonnes of wheat. Phosphine blankets were placed in the silo headspace with no recirculation. It took as long as 5 days for all grain at the silo base to reached at least 200 ppm gas concentration.

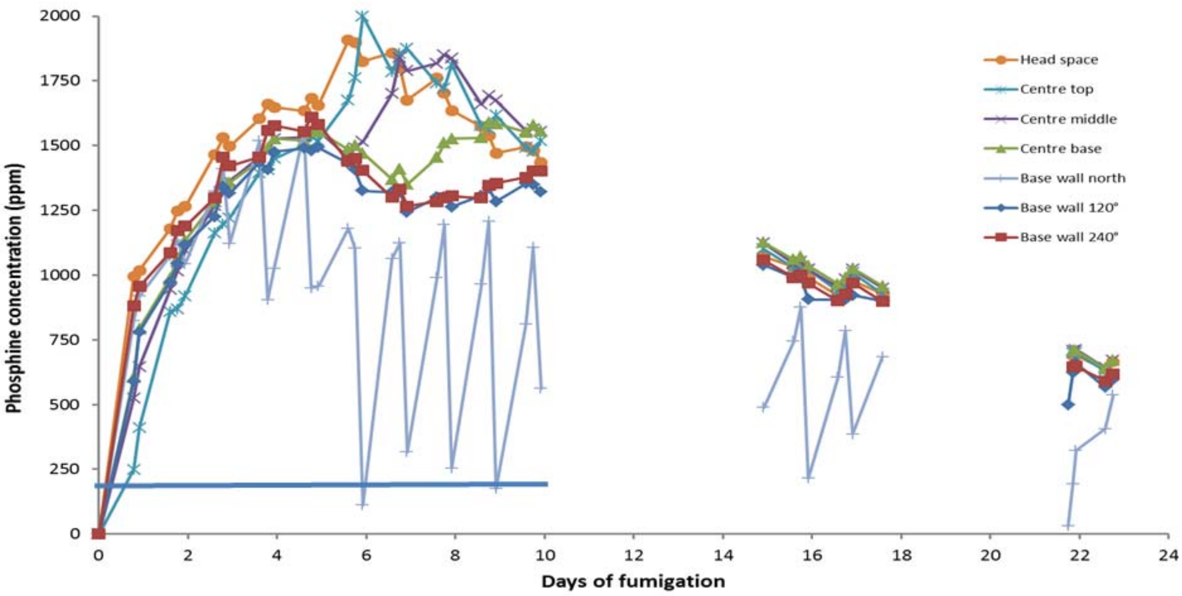


Figure 6. Phosphine gas concentations in a silo (1423 t wheat) where a small fan was used to draw gas from blankets in the silo headspace and pump it to the silo base via aeration ducts for the first 5 days of fumigation. Gas concentration in all areas of the silo reached over 800 ppm within the first 24 hrs.

Figure 7. A small fan (F370 – 0.37 kW) used during the first 5 days of fumigation to recircualte phosphine to give rapid uniform gas distribution in 1423 tonnes wheat. See Figure 6.

Options for fumigation recirculation

For all fumigation recirculation systems, the sealable silo needs to be gas – tight so there is no gas leakage during the fumigation. Fig. 6, "Base wall north" shows the impact of a leak at the silo manhole which causing large daily fluctuations in gas concentrations.

a) Phosphine blankets or tablets can be placed in the 'silo headspace' along with a small fan connected to the headspace via 90 mm pipe plumbing coming down the silo wall from the roof. Phosphine gas is drawn from the headspace and pumped into the base of the silo via both aeration ducts. See Fig. 7

b) For ground level application of tablets or blankets, a sealable 'phosphine box' can be plumbed into this system, either a moveable box, or mounted permanently on each silo.

c) Using a fan to force the phosphine gas movement around in silos during fumigation is generally recommended, rather than relying on a passive 'thermosiphon' approach. For medium and large silo fumigations, 150 tonnes plus, or silos storing smaller grain sizes (e.g. millets, canola, lentils etc.) that reduces air movement, fan force recirculation rather than thermosiphon is advised. Fan forced recirculation may also assist where the grain type (e.g. oilseeds) typically absorbs higher amounts of phosphine during fumigation.

Equipment for fumigation recirculation

- Sealable silo - gas tight, that passes pressure test
- Plumbing pipes (90 – 100 mm) from silo roof to ground level. Use quality pipe, fittings and seals that will ensure many years of safe, gas- tight fumigations
- Small fan (e.g. Downfield F370 - 0.37 kW) to recirculate air. In most case this fan size will be suitable for both small & large silos. In trials (Fig. 6 & 7) this fan size provided a complete silo air change every 12 hours for the full silo holding 1420 tonnes of wheat
- Fittings for fan intake and outlet. Flexible hoses (50 – 100mm) couplings and gate valves

Fumigation recirculation - operations

a. Pressure test the silo to check for leaks

b. Follow all label directions and place tablets / blankets in the 'headspace' or 'phosphine box'.

c. Run small recirculation fan for first 5 days of fumigation. Leave silo sealed for remaining days of fumigation expose period as label requires (e.g. 7, 10, 20 days).

   Note: There are benefits to using the silo 'headspace' to locate the blankets or tablets. The large surface area of grain in the headspace provides safe, large easy access for gas penetration and diffusion into the grain.

Warning

Always seek reliable advice before fitting fumigation recirculation systems to silos / storages. Some systems that are currently sold are not recommended because of unsafe design features. Phosphine is not only a toxic gas, but can be flammable and explosive if restricted in a small area or used in a manner that causes gas concentrations to rise quickly to high levels.

Follow label directions and seek advice.

Further reading

- GRDG Factsheet – "Performance testing aeration systems"
  http://storedgrain.com.au/testing-aeration/
- GRDC Fact Sheet – "Safe storage of Sunflower seed – aeration drying and cooling"
  http://storedgrain.com.au/safe-storage-sunflower-seed/
- GRDC Update – "How Aeration Works"
  http://storedgrain.com.au/how-aeration-works-grdc-update/
- GRDC booklet – Aeration stored Grain – cooling or drying for quality control
  http://storedgrain.com.au/aerating-stored-grain/
- GRDC booklet – Fumigating with Phosphine other fumigants and controlled atmospheres
  http://storedgrain.com.au/fumigating-with-phosphine-and-ca/
- GRDC video – Fumigation recirculation
  http://storedgrain.com.au/fumigation-recirculation/

Acknowledgements

The research undertaken is made possible by the significant contributions of growers through both trial cooperation and support of GRDC, DAF Postharvest research team and GRDC's national grain storage extension team, the author would like to thank them for their continued support.

Contact details

Philip Burrill
Department of Agriculture & Fisheries, AgriScience Qld.
Hermitage research facility, 604 Yangan road, Warwick Qld. 4370
Mob: 0427 696 500
Email: philip.burrill@daf.qld.gov.au

Investment in on-farm storage and the grain supply chain

Andrew Freeth, 'Fairfield' Gilgandra, Nuffield Farming Scholar

Key words

Grain storage, grain supply chain, on farm storage

Take home message

Growers considering investment in On Farm Storage (OFS) should establish clear objectives, consider future needs and plan with potential expansion in mind. Long term, the growth trajectory of OFS investment will be driven by the service offering from the commercial bulk handlers and also by the growth in domestic grain production and consumer needs. Managing relationships with supply chain partners is critical if growers are to effectively take on a greater role in the supply chain.

On-farm storage and the grain supply chain

It is likely that Australian growers will continue to increase overall On Farm Storage (OFS) capacity and improve the quality and sophistication of existing infrastructure. This trend is currently being driven by:

- harvest logistics and increased harvester capacities;
- rationalisation of the upcountry grain storage network;
- the increased area sown to pulse and specialty crops;
- government incentives to invest;
- increases in overall grain production and
- greater willingness of growers to have greater control of their grain path to market stemming from strong recent returns from selling grain ex-farm relative to the Bulk-Handler system.

Australia's lack of an effective freight 'System' feeding main line rail in Eastern Australia is a constraint on productivity for the grains industry. Australian East-coast below rail assets do not currently meet the needs of a modern grain supply chain. State and Federal Governments have a challenge to ensure policy settings exist, including alternative funding sources to facilitate and fast track investment. The long term future of grain logistics in Eastern Australia will be heavily influenced by the construction of a Melbourne–Brisbane inland rail freight link. Sub section construction timelines will be an important component of this project. Governments also need to consider market led road upgrades that safely enable longer road combinations and enhanced productivity on strategically important grain road routes.

The grains industry relies on fumigation with Phosphine gas to kill stored grain pests with few commercial alternatives available. The future management of grain in store will need to consider alternatives for maintaining grain in a saleable condition. The industry needs to maintain focus on fumigating in gas tight storage that meets Australian standard AS2628 to maximise the longevity of phosphine as a fumigant. The best alternative strategy to fumigation is to:

- limit the incursion of stored grain pests and by using good hygiene practices;
- adequate monitoring and cooling grain using automated aeration systems, and
- the use of grain protectants, subject to market requirements.

Acknowledgements

The author would like to thank the GRDC for supporting the research undertaken.

Contact details

Andrew Freeth
Nuffield Farming Scholar
'Fairfield', Gilgandra, NSW, 2827.
Ph: 0407 205 503
Email: adfreeth@gmail.com

Harvest weed seed control systems for the northern region

Michael Walsh, Director Weed Research, University of Sydney

Key words

IHSD, Chaff tramlining, HWSC

GRDC code

UWA00171

Take home message
Chaff tramlining is a simple, effective approach to harvest weed seed control (HWSC) that removes the need for residue burning for HWSC. This system is particularly suited to high residue situations with dedicated tramlines. The newly commercialised iHSD is a more sophisticated approach to HWSC where two hydraulically driven chaff processing mills are neatly fitted to the rear of the harvester. This highly effective system also reduces the need for residue burning but has the added advantage of retaining and redistributing all residues back across the paddock.

Background

There are now several commercially available HWSC methods that effectively target the weed seed bearing chaff fraction during crop harvest. Studies on the efficacy of these practices: narrow windrow burning, chaff carts, bale direct (BDS) and Harrington Seed destructor (HSD) have clearly demonstrated their efficacy in preventing inputs of viable inputs of seed into the seed bank (Walsh et al., 2014; Walsh et al., 2012; Walsh and Newman, 2007; Walsh et al., 2013). However, single system is suited for use across all of Australia's crop production regions and situations. Therefore, there remains a need for the availability of multiple systems and the ongoing development and refinement of current HWSC options. Two relatively new systems, chaff tramlining and the iHSD have recently been introduced and expectations are that their adoption will be high in the northern cropping region.

Chaff tramlining

The practice of concentrating chaff material on dedicated tramlines is termed chaff tramlining where weed seeds are placed in a hostile environment from which it is difficult for germination and emergence. As with all other HWSC systems chaff tramlining focuses on the weed seed bearing chaff fraction and therefore, depending on seed survival has the potential to be similarly effective. In a trial at North Parkes, NSW, comparing narrow windrow burning and chaff lining with conventional harvest both HWSC systems resulted in a 60% reduction in annual ryegrass emergence.

A study evaluating over summer annual ryegrass seed survival at Esperance, WA highlighted the hostile nature of the chaff tramline environment. There was very low seed survival for annual ryegrass seed placed under canola and barley (Table 1). Interestingly though survival was considerably greater for seed placed under wheat chaff. This is despite similar levels of chaff biomass for wheat and barley in particular. At the second time of assessment only annual ryegrass seed beneath the wheat chaff was surviving. At this stage it is not known why there are large differences in seed survival between the different chaff types but obviously this will have a significant effect on the efficacy of chaff tramlining.

Table 1. Survival of annual ryegrass seed at seeding and crop anthesis following placement under a chaff tramline during the previous harvest.

Chaff type	Chaff (t/ha)	Survival (%)	
		At seeding	Anthesis
Canola	31	2	0
Wheat	19	74	10
Barley	18	3	0

Integrated Harrington Seed Destructor (iHSD)

The iHSD is now commercially available as a retrofit system for harvesters in Australia. Testing of the weed seed destruction efficacy of this mill system over the last two seasons has determined that there was similarly high efficacy as the cagemill used in the trail behind HSD system (Table 2). Very high level s of seed destruction were recorded for the four dominant species of Australian cropping, annual ryegrass, wild radish, wild oats and brome grass.

Table 2. Effect of iHSD mill processing of wheat chaff on the seed mortality of four weed species.

Weed species	Seed kill (%)	SE
Annual ryegrass	93	0.7
Wild radish	99	0.2
Wild oats	99	0.1
Brome grass	99	0.2

High weed seed destruction levels were recorded when the iHSD mill system was evaluated under commercial harvest conditions. During the harvest of canola and barley crops known numbers of annual ryegrass, wild radish, wild oat and brome grass seed were introduced to an iHSD mill fitted to a class 9 harvester. Processed chaff was collected and sieved and sorted to recover viable weed seeds. In all instances there was 99% kill of the introduced weed seed.

Summary

The number of HWSC options continues to grow as producers look to utilise this approach to weed control in cropping systems. The iHSD is now commercially available following several years of field stationary mill testing that have proven its efficacy and commercial capacity. Chaff tramlining is becoming widely adopted as growers move to tramline systems and look to reduce residue burning in their production systems. Both approaches are highly effective weed control tools and can provide considerable support for herbicide based weed management programs.

References

Walsh MJ, Aves C, Powles SB (2014) Evaluation of harvest weed seed control systems. Pages 288-291 *in* Barker M, ed. 19th Australasian Weeds Conference. Hobart, Tasmania: Tasmanian Weed Science Society

Walsh MJ, Harrington RB, Powles SB (2012) Harrington seed destructor: A new nonchemical weed control tool for global grain crops Crop Science 52:1343-1347

Walsh MJ, Newman P (2007) Burning narrow windrows for weed seed destruction. Field Crops Research 104:24-40

Walsh MJ, Newman P, Powles SB (2013) Targeting Weed Seeds In-Crop: A New Weed Control Paradigm for Global Agriculture. Weed Technology 27:431-436

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. Particularly like to thank farmer co-operators Ray Harrington, Mark Wandel, Michael Fels and Matt Burkitt.

Contact details

Michael Walsh
University of Sydney
Locked Bag 1100
Ph: 02 67992201
Mob: 0448 847 272
Email: m.j.walsh@sydney.edu.au

Fallow Management of Grass Weeds

Richard Daniel, Northern Grower Alliance

Key words

Awnless barnyard grass, feathertop Rhodes grass, liverseed grass, button grass

GRDC code

NGA00004: GRDC Grower Solutions for Northern NSW and Southern Qld

Take home messages

1. Effective fallow management of key summer grass weeds - relying on glyphosate alone – is increasingly unsustainable

2. Need to incorporate a range of other tactics including double-knocks and residual herbicides to assist management

3. Knockdown options can be effective but heavily rely on preplanning and being able to target small growth stages

4. Suitable tactics will vary by weed species but in all cases there is a need to utilise as many non-chemical approaches as practical

5. Individual paddock rotations may need to change to enable use of effective residual chemistry in fallow or in-crop

The issue

Grass control in the summer fallow has become an increasingly difficult and expensive component of many northern farming systems in recent years. At least part of the reason has been due to the heavy reliance on glyphosate. This has selected weed species that were naturally more glyphosate tolerant or selected for glyphosate resistant populations.

Although this paper will focus on chemical management of these weeds, it is clear we need to better understand and employ other weed management tactics to successfully and economically control these significant threats to cropping.

1. **Awnless barnyard grass (*Echinochloa colona*)**

Awnless barnyard grass (ABYG) has been a major summer grass issue for many years. It is a difficult weed to manage for at least three key reasons:

1. Multiple emergence flushes (cohorts) each season
2. Easily moisture stressed, leading to inconsistent knockdown control
3. Glyphosate resistant populations are becoming widespread

Resistance levels

Prior to summer 2011/12, there were 21 cases of glyphosate resistant ABYG. Collaborative survey work was conducted by NSW DPI, DAF Qld and NGA in summer 2011/12 with a targeted follow-up in 2012/13. Agronomists from the Liverpool Plains to the Darling Downs and west to areas including Mungindi collected ABYG samples that were tested at the Tamworth Agricultural Institute.

The key outcome was that the number of 'confirmed' glyphosate resistant ABYG populations had nearly trebled. Selected populations were also evaluated in a glyphosate rate response trial. This showed that some of these populations were still only suppressed when sprayed with 12.8 L/ha.

Additionally it has been found recently that the glyphosate 'resistance' expression is increased when conditions are warmer i.e. glyphosate resistant populations are even 'more resistant' under hotter temperatures.

The days of solely relying on glyphosate for ABYG control are behind us.

Residual herbicides (fallow and in-crop)

There are a range of active ingredients registered in either summer crop e.g. metolachlor (e.g. Dual Gold®) and atrazine or in fallow e.g. imazapic (e.g. Flame®) that provide useful management of ABYG. The new fallow registration of isoxaflutole (e.g. Balance®) can provide useful suppression of ABYG but has stronger activity against other problem weed species. Few, if any, residual applications will provide complete control. However they are important tools that need to be considered to reduce the population size exposed to knockdown herbicides as well as to alternate the herbicide chemistry being employed. Use of residuals together with camera spray technology (for escapes) can be a very effective strategy in fallow.

Double-knock control

This approach uses two different tactics applied sequentially. In reduced tillage situations, it is frequently glyphosate first followed by a paraquat based spray as the second application or 'knock'. Trials have shown that **glyphosate followed by paraquat can give effective control even on glyphosate resistant ABYG but timing and stress are important**. Ensure glyphosate rates are robust. Another strategy can be to use paraquat as both 'knocks', particularly for populations where glyphosate effectiveness has been poor.

Timing of paraquat application as the second "knock" for ABYG control has generally proven flexible. The most consistent control is obtained from a delay of ~3-5 days, which also can allow for lower rates of paraquat to be used. Longer intervals may be warranted when ABYG is still emerging at the first application timing, shorter intervals are generally required when weed size is larger or moisture stress conditions are expected. High levels of control can still be obtained with larger weeds but paraquat rates will need to be increased to 2.0 or 2.4 L/ha.

Knockdown control

A number of Gp A herbicides eg haloxyfop (e.g. Verdict®) and eg clethodim (e.g. Select®) are effective on ABYG but are only registered in summer crops such as mung beans. NB Gp A herbicides are generally more sensitive to weed moisture stress or size. Application to large or mature weeds can result in poor efficacy.

Key points ABYG

- Glyphosate resistance is widespread. **Tactics against this weed must change from glyphosate alone**
- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology
- Try to ensure a double-knock of glyphosate followed by paraquat is used on one of the larger early summer ABYG flushes
- Utilise Gp A herbicides in crop and aim for strong crop competition
- Cultivation can be very effective on this weed but multiple emergences are likely each summer season

2. Feathertop Rhodes grass (Chloris virgata)

Feathertop Rhodes grass (FTR) started to become an important weed in southern Qld and northern NSW in ~2008. It is a small seeded species that germinates on, or close to, the soil surface. It has rapid early growth rates and easily becomes moisture stressed.

Some likely reasons for the difficulty of managing this weed are:

- It is a species with higher levels of natural tolerance/resistance to glyphosate and has been selected by glyphosate dominated fallow/roadside management strategies
- It is frequently poorly controlled by paraquat alone or even a double-knock of glyphosate followed by paraquat
- QDAF research showed FTR is one of the first weed species to colonise bare areas and can germinate on smaller rainfall events than many other problem species
- Minimum/zero tillage practices are likely to have contributed to the threat posed by this weed as cultivation or seed burial (to depths of 2cm or deeper) can be effective management tools

Three characteristics that can be useful to assist FTR control are that:

1. Seed viability does not appear to be improved by seed burial (in contrast to many other weed species)
2. Seed longevity is short (~12 months). If effective control strategies can be used for a period of ~12-18 months, the seedbank of FTR can be rapidly run-down.
3. New incursions of FTR are often in well-defined patches (in contrast to weeds such as common sowthistle). Aggressively treatment of these patches can prevent whole of paddock blow-outs

Residual herbicides (fallow)

Evaluation of a wide range of residual herbicides has shown a number of promising candidates for FTR management. Currently the only registered product for residual control in fallow is Balance®. Additional product registrations for fallow use are being sought.

Residual herbicide (in-crop)

Utilising residual herbicides in-crop will allow the use of additional weed management approaches. In-crop use benefits from:

- Crop competition
- Change in crop being grown and available herbicide options
- Herbicide application often under more favourable conditions than in fallow or where a level of mechanical incorporation occurs
- ‘Increased disturbance’ planting may provide benefits for FTR management via weed seed burial or removal of early weed emergence

Currently there are no registrations for residual control of FTR in-crop. Residual herbicide strategies for awnless barnyard grass control (e.g. Dual® Gold, Flame®, trifluralin eg TriflurX® and pendimethalin eg Stomp® Xtra) applied in a range of summer crops have been noted to reduce the emergence of FTR.

FTR is predominantly a summer weed but the first cohort of emergence can occur during the winter crop phase. Screening of herbicides, currently registered for residual control of other weeds, in winter cereal or chickpea production has shown encouraging levels of activity. Residual herbicide strategies for the control of a range of both grass and broadleaf weeds (e.g. Balance®, Treflan®, Stomp®, Sakura® and terbuthylazine eg Terbyne® Xtreme) applied in a range of winter crops have been noted to reduce the emergence of FTR.

Residual herbicides for FTR in non-crop situations

FTR frequently dominates in non-crop areas with a potential for re-infestation of adjacent areas. For non-crop areas, there is a registration for 7L/ha of imazapyr 150g/L (eg Arsenal®).

Knockdown herbicides (in-crop)

The main registrations for knockdown of FTR are from the use of Gp A (grass selective) herbicides in cotton, mungbeans and other broadleaf summer crops.

Double-knock control

Glyphosate followed by paraquat is generally an effective strategy for ABYG management. However the same approach is rarely effective for FTR management. In contrast, a small number of Gp A herbicides (all members of the 'fop' class) can be effective against FTR but need to be managed within a number of constraints:

- Although they can provide high levels of efficacy on fresh and seedling FTR, they need to be followed by a paraquat double-knock to get consistent levels of control
- Gp A herbicides have a high risk for resistance selection, again requiring follow up with paraquat
- Many Gp A herbicides have plantback restrictions to cereal crops
- Gp A herbicides generally have narrower growth stage windows for successful use than herbicides such as glyphosate ie Gp A herbicides will generally give unsatisfactory results on flowering and/or moisture stressed FTR
- Gp A herbicides vary in their effectiveness on FTR

A permit (PER12941) is valid until 31/8/2019, in Qld only, for the control of FTR in summer fallow situations prior to planting mungbeans. The permit is for the application of haloxyfop 520 g ai/L formulations (eg Verdict®) at 150-300mL/ha followed by paraquat at a minimum of 1.6 L/ha, within 7-14 days after the first application. In addition there has been a recent registration of Shogun® for FTR management in fallow but only when followed by a paraquat double-knock.

Key points

- Glyphosate alone or glyphosate followed by paraquat generally unsatisfactory
- Utilise residual chemistry wherever possible and prepare a plan to control 'escapes' e.g. camera spray technology
- Utilise aggressive patch management for new incursions (including manual weeding and chipping) and preferably follow up with residual herbicides over previous patches where weeds may have seeded

Other tactics to consider

- Salvage cultivation is often the most effective and economic tool for mature plants
- Consider (infrequent) strategic cultivations for seed burial (repeated tillage may simply return seeds to the soil surface)
- Burning appears a useful tool where blow outs have occurred in patches or even in larger areas to reduce seed viability

3. Liverseed grass (Urochloa panicoides)

Liverseed grass is another widespread weed in the northern grains region. Unlike ABYG, Liverseed grass is generally noted for a single main emergence flush each season.

Residual herbicides (fallow)

The only product currently registered for residual control in fallow is Flame®. Evaluation of a wide range of residual herbicides has generally shown inconsistent residual control of Liverseed grass (particularly compared to ABYG and FTR).

Residual herbicide (in-crop)

There are a number of residual herbicide options registered for in-crop use eg Dual® Gold, TriflurX®, Stomp® Xtra and imazamox eg Raptor®). A good strategy for paddocks with high seed burdens of liverseed grass seed is to grow crops that allow the use of these residual herbicides. Use of these herbicides in registered winter crops can also assist in liverseed grass management.

Double-knock control

A double knock of glyphosate followed by paraquat is generally an effective option with paraquat followed by paraquat also an option to consider. The paraquat followed by paraquat approach is likely to be more successful particularly on moisture stressed populations.

Knockdown control

A number of Gp A herbicides eg Verdict® and Select® are effective on Liverseed grass but are only registered in summer crops such as mung beans. NB Gp A herbicides are generally more sensitive to weed moisture stress or size. Application to large or mature weeds can result in poor efficacy.

4. Button grass (*Dactyloctenium radulans*)

Button grass is generally a more localised weed threat than ABYG or liverseed grass. It prefers lighter soils and is often one of the first weeds to emerge after rain events. Button grass often appears as the first weed species to enter moisture stress.

Residual herbicides (fallow or in-crop)

Very restricted range of options. The only product currently registered for residual control in fallow is Flame®. The only product currently registered for residual control in-crop is Stomp® Xtra.

Use of these residuals on small infestations of button grass (eg on sandy ridges) may allow more targeted and timely knockdown applications.

Double-knock control

Trial work in 2015/16 showed a double knock of glyphosate followed by paraquat as an effective option together with paraquat followed by paraquat. Large rate responses were seen to glyphosate alone. It is important to keep the glyphosate rates robust.

There are no currently registered in-crop knockdown options.

Conclusions

Profitability is of course still paramount. The suggestion with these problem weeds is to focus on individual paddocks and adjust rotations to crops that most suit your environmental conditions but also enable the use of effective residual herbicides in the previous fallow or even in crop. Particularly for FTR, the seed bank appears only short lived and two years of effective management can ensure that paddocks return to full flexibility of rotational choice.

Acknowledgments

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

Contact details

Richard Daniel
Northern Grower Alliance
Ph: 07 4639 5344
Email: richard.daniel@nga.org.au

® Registered trademark