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AGENDA		
Time	**Topic**	**Speaker(s)**
9:00 AM	Welcome	John Minogue, GRDC
9:10 AM	**Fallow management** – managing problem grass weeds and glyphosate resistant sow thistle	Richard Daniel, NGA
9:40 AM	**Herbicide volatility and spray drift** - boom setups for different types of spray jobs - summer fallow, post-emergent graminicides, pre-emergent herbicides in stubble and late season fungicides/insecticides for canopy penetration • Boom height impacts on drift • Air assist booms - where can they assist? • Spraying without driftable fines – is it possible?	Bill Gordon, Nufarm
10:10 AM	**Wheat disease update** • Rust • Fusarium	Steven Simpfendorfer, NSW DPI
10:30 AM	Morning tea	
11:00 AM	**Barley disease update** • New barley seed treatment - performance in northern trials • Leaf rust in Compass(b) • Increased levels of NFNB in Commander(b) & Shepherd(b) barley • Loose smut in some barley varieties in 2016 • Scald and other wet season diseases - what did we learn in 2016?	Lislé Snyman, DAF Qld
11:20 AM	**Nitrogen timing and placement** - does early fallow timing provide better nitrogen use efficiency?	Rachel Norton, NGA
11:45AM	**Denitrification and managing nitrogen loss risk** - key factors affecting loss, scenarios and case studies	Chris Dowling, Back Paddock Co
12:25 PM	Lunch	
1:25 PM	**Cereal agronomy** – tweaking cereal agronomy to optimise profit from newer varieties	Guy McMullen, NSW DPI
1:55 PM	**Advances in canola agronomy** - how phenology contributes to decision making	Rick Graham, NSW DPI & Jeremy Whish, CSIRO
2:25 PM	**Fababean disease management**	Joop van Leur, NSW DPI
2:45 PM	**Chickpea disease update** - lessons from 2016 and recommendations for 2017	Kevin Moore, NSW DPI
3:15PM	Close	

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Fallow management of grass weeds and common sowthistle

Richard Daniel, Northern Grower Alliance

Key words

Awnless barnyard grass, feathertop Rhodes grass, liverseed grass, button grass, windmill grass, common sowthistle

GRDC code

NGA00004

Take home messages

- Effective fallow management of key summer grass weeds and common sowthistle - relying on glyphosate alone - is increasingly unsustainable
- Need to incorporate a range of other tactics including double knocks and residual herbicides to assist management
- Knockdown options can be effective but heavily rely on preplanning and being able to target small growth stages
- Suitable tactics will vary by weed species but in all cases there is a need to utilise as many non-chemical approaches as practical
- 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 (confirmed with laboratory testing) 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 ie 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 Group 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 Group 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 Group 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® 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. It is noted that none of these products have an in-crop registration for control of feathertop Rhodes grass.

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 and glyphosate 150g/L (eg Arsenal Xpress®).

Knockdown herbicides (in-crop)

The main registrations for knockdown of FTR are from the use of Group 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 Group A herbicides 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
- Group A herbicides have a high risk for resistance selection, again requiring follow up with paraquat
- Many Group A herbicides have plantback restrictions to cereal crops
- Group A herbicides generally have narrower growth stage windows for successful use than herbicides such as glyphosate ie Group A herbicides will generally give unsatisfactory results on larger stressed weeds
- Group 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 bipyridyl double knock as per label instructions.

Key points FTR

- Glyphosate alone or glyphosate followed by paraquat is generally unsatisfactory
- Utilise residual chemistry wherever possible and prepare a plan to control ‘escapes’ eg 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® 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 Group A herbicides eg Verdict® and Select® are effective on Liverseed grass but are only registered in broadleaf summer crops, e.g; mung beans. NB Group 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®.

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.

5. Windmill grass (*Chloris truncata*)

FTR has been a grass weed threat coming from Qld and heading south, windmill grass (WG) is more of an issue in central NSW but is spreading north. WG is a perennial, native species found throughout northern NSW and southern Qld. The key cropping threat appears to be from the selection of glyphosate resistant populations with control of the tussock stage providing most management challenges.

Residual herbicides (fallow and in-crop)

Preliminary trial work has shown a range of residual herbicides with useful levels of efficacy against WG. These herbicides have potential for both fallow and in-crop situations. **Currently there are no products registered for residual control of WG.**

Double knock control

Similar to FTR, a double knock of a Group A herbicide followed by paraquat has provided clear benefits compared to the disappointing results usually achieved by glyphosate followed by paraquat. Similar constraints apply to double-knock for WG control as they do for FTR.

- Although some Group A products can provide high levels of efficacy on fresh and seedling WG, they need to be followed by a paraquat double-knock to get consistent high levels of final control
- Group A herbicides have a high risk for resistance selection, again requiring follow up with paraquat
- Many Group A herbicides have plantback restrictions to cereal crops
- Group A herbicides generally have narrower windows of weed growth stage for successful use than herbicides such as glyphosate ie Group A herbicides will generally give unsatisfactory results on larger or stressed weeds.

A permit (PER13460) has been issued, in NSW only (only valid until March 31, 2017), for the control of WG in summer fallow situations. It is for quizalofop-p-ethyl (e.g. Targa® 99.5 g ai/L or 100 g ai/L products at 0.5-1.0 L/ha) followed by paraquat at a minimum of 1.6 L/ha, within 7 days after the first application. Use of 200 g ai/L quiazalofop-p-ethyl formulations is also permitted at 0.25-0.5 L/ha. First application should be at WG growth stages between 3 leaf and early tillering.

Timing of the second application for WG is still being refined but application at ~7-14 days generally provides the most consistent control – however the permit requires application within 7 days. Application of paraquat at shorter intervals can be successful, but has resulted in more variable control in field trials and has been clearly antagonistic when the interval is one day or less.

Key points Windmill grass

- Glyphosate alone or glyphosate followed by paraquat is generally poor.
- Preliminary data suggests that residual chemistry may provide some benefit
- A double-knock of quizalofop-p-ethyl (e.g. Targa) followed by paraquat can be used in NSW

6. Common sowthistle (*Sonchus oleraceus*)

Common sowthistle is one of the most widespread broadleaf weeds in the northern cropping region with seed very easily dispersed by wind. It was once considered a winter weed but has become an issue all year round.

The two biggest challenges with common sowthistle are management of glyphosate resistant populations and the successful fallow control of large weeds. NGA have been evaluating options for residual, knockdown or double knock approaches during the last 18 months.

Residual herbicides (fallow or in-crop)

Products currently registered for residual control in fallow include Balance and Terbyne® Xtreme. Balance, Terbyne Xtreme and simazine are all registered for in-crop residual control. NGA have been involved in screening other herbicides for residual control of common sowthistle with encouraging results from members of other herbicide mode of action groups.

Double knock control

Using a double knock of glyphosate followed by paraquat can be an effective tool on small common sowthistle eg 4-8 leaf but generally leads to variable control, at best, on larger rosettes and at more advanced growth stages. Evaluation of alternative first knock candidates indicates that Group I products followed by paraquat are providing improved levels of efficacy compared to glyphosate followed paraquat on larger rosettes. Many of these options are used for fleabane control and often provide a level of residual activity.

Basta® (200g/L glufosinate ammonium) followed by paraquat appears promising but is likely to be restricted to optical spray situations due to the high cost. Screening is also underway for alternative 2nd knock herbicides to paraquat.

Knockdown control

There are limited knockdown (single knock) options for common sowthistle. Sharpen® is registered for use in mixture with glyphosate. This can be an effective tool but needs to be applied on very small weeds for consistent control. Basta alone is also registered and maybe a consideration in 'non-broadacre' spray situations. Trial work in 2016/17 has shown promising knockdown activity from optical sprayer rates of Basta on larger common sowthistle.

Key points

- Commercially unacceptable efficacy from glyphosate or glyphosate followed by paraquat is becoming more widespread.
- The industry must develop 'non-glyphosate' based management strategies
- Residual chemistry clearly has a benefit with encouraging levels of activity from a range of herbicide mode of action groups.
- Double knocks of Group I herbicides followed by paraquat appear promising and may be suitable where grass weeds are of less concern.
- Basta may become an option, primarily through optical sprayer setups, but more work is needed to ensure robustness across a range of environmental conditions.

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.

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Spray application tips and tactics

Bill Gordon, Nufarm Australia

Key words

Spray application, spray coverage

Take home message

Product choice and rate, timing and total application volume will normally have the largest impacts on the efficacy achieved from any spray job. The sprayer setup and operating parameters can also have a significant effect on the outcome by affecting the spray coverage on the target, as well as the drift potential. Assessing spray coverage is a simple process that can help to improve the sprayer setup.

Introduction

Throughout the season there are a number of situations where spray applications are made to very different types of targets, often with products that have different types of translocation. This variation generally requires a change in nozzle type or orifice size and the operating parameters to achieve a change in total application volume and/or spray quality.

After adjusting the sprayer setup, being able to determine where the spray droplets are landing allows the operator to change the sprayer setup to improve the coverage for particular spray jobs. Often this requires that the operator is able to assess the impact of changes to the set up on where the droplets land.

A starting point – how many setups should the operator have?

As a general guide, the main spray jobs, application volumes and typical spray qualities required by an operator are covered in table 1. This highlights the fact that often more than 2 sets of nozzles are required to cover all situations.

For each type of spray application there may be subtle variations in the sprayer setup or operation that can be made to improve the coverage. This paper discusses some of the practical considerations the operator should take into account when choosing the set up for various spray jobs throughout a typical season, including the factors influencing spray coverage and how to compare setups and operating parameters for continual improvement.

Table 1. Typical spray quality and total application volume for different situations

Typical Application Volume	Medium Spray Quality (lower drift risk areas)	Coarse Spray Quality	Extremely Coarse Spray Quality (higher drift risk areas)
Lower range **50 -60 L/ha** **(Low stubble load)** **to** **70-80 L/ha** **(High stubble load)**	*Only where permitted on label: Fully translocated herbicides Small to medium sized targets.	Fallow Spraying Fully translocated herbicides such as Glyphosate and Group I herbicides,	Fully translocated herbicides, medium targets, Very sensitive areas or NIGHT SPRAYING
Higher range **70-80 L/ha** **(Low stubble load)** **to** **100 + L/ha** **(High stubble load/ dense crop canopy)**	*Only where permitted on label: Contact type products. Small targets. In crop spraying. Penetration and coverage in large & broadleaf crops.	Good stubble penetration. Pre-emergent's. Fully Translocated herbicides, Some contact herbicides at the higher application volumes.	Water soluble Pre-emergent's. Medium sized targets with fully translocated summer fallow herbicides. Very sensitive areas or NIGHT SPRAYING

*note, the arrows indicate that one nozzle may be able to do more than one type of application, provided the spraying speed, application volume and operating pressure are suitable

Suggestions to improve fallow applications

The following points have been included to provide a guide or starting point for the sprayer setup. Some of the important things to consider include:

Total application volume: For fully translocated products typically volumes above 50L/ha for a coarse spray quality in low stubble environments, and above 70L/ha in heavy stubble environments. Typically this volume should be increased by 10 to 20 L/ha when using an extremely coarse spray quality. For contact type products (translaminar) the total application volume should be above 70L/ha in low stubble environments, and up to 100 L/ha in heavy stubble situations.

Spray quality: For small vertical targets (grasses) operating at the small end of the coarse spectrum will normally provide good retention of droplets on a range of weed types, however using coarser spray qualities may also be useful for many broadleaf weeds. Often operating at the small end of the coarse spectrum will provide a good balance for a range of targets and products. This is normally suitable for daytime conditions, but may not reduce the spray drift potential if considering spraying at night.

Nozzle spacing: Using narrow nozzle spacings, e.g. 25cm compared to 50cm, can improve deposition into standing stubble. However before deciding to plumb the machine this way ensure that the orifice size and spray quality will be suitable if operating with nozzles that have smaller orifice sizes.

Boom Height: Operating at heights above that required for a double overlap at top of the stubble or weed (whichever is the taller) will reduce coverage and increase drift potential. Increasing boom height from 50cm above the target to 70cm above the target can increase the airborne fraction of spray by up to 4 times.

Adjuvant selection: adjuvants should always be chosen to increase efficacy, however many adjuvants have the potential to change the spray quality and drift potential in unexpected ways. Most non-ionic wetter 1000 type products can more than double the drift potential from some air

inducted coarse nozzles. For fallow spraying it is important to select adjuvants that do not increase the drift potential of the spray application.

Spraying speed: Reducing spraying speed can reduce dust and wheel tracks, will improve penetration into stubble and crop canopies and can reduce shadowing.

Nozzle design: There are a number of nozzle designs that have twin patterns, where one pattern is angled forward and the other angled backwards. Generally twin nozzles are best utilised for increasing deposition onto vertical targets, which may also increase stubble interception. Twin nozzles are best operated at lower spraying speeds, commonly less than 16 km/h.

Risk assessment: Before any spray application it is important to fully assess any risks including the weather conditions, sensitive areas and volatility risk.

Pre-emergent herbicides

Most applications of pre-emergent herbicides will benefit from using coarser spray qualities to increase penetration through stubble and by increasing the total application volume, however volumes above 150 L/a generally do not provide further significant improvements in efficacy.

For products with relatively low water solubility, such as trifluralin and pendimethalin, avoiding the tie up of product onto stubble is critical to maximising herbicide contact with the soil. When using a conventional nozzle spacing of 50cm, a VC spray quality or larger (such as XC) set to produce a double overlap at the top of the stubble can minimise retention on stubbles, however the uniformity of the spray deposit onto the soil surface will be more variable than compared to a coarse spray quality due to the lower number of droplets produced.

For reasonably water soluble products such as atrazine, simazine and metalochlor, interception by the stubble may have a smaller impact on efficacy, provided a reasonable rainfall event can wash the product back onto the soil. Where rainfall is anticipated, the more water soluble products may be applied in a lower total application volume, typically above 70-80 L/ha.

Generally reducing spraying speeds will improve the penetration into stubble and improve the evenness of the application. Narrower nozzle spacings can also be of benefit, provided the spray quality and boom height are suitable.

Alternately, many operators have plumbed machines with nozzle spacings to match the crop row width. Where nozzles are positioned in the centre of the inter-row gap between standing stubble lines, the nozzle height may be lowered to obtain an overlap close to the base of the stubble. This may improve soil contact and reduce interception by the stubble, provided spraying speeds and wind speeds do not excessive.

Early season grass sprays in-crop

Droplet retention on small, vertical grasses is usually optimised when using a medium spray quality (where permitted on label), however in a heavy standing stubble, the smaller droplet sizes tend to increase the amount of product deposited onto the stubble. Generally a spray quality at the smaller end of the coarse spectrum (towards medium) combined with total application volumes above 70-80 L/ha will provide a reasonable outcome.

Where operators typically operate at higher spraying speeds, or with larger than coarse droplets, they may notice increased shadowing of small weeds behind stubble. Where this is occurring, slowing down would help, but ensuring that each new job is driven in the opposite direction to the last can also improve overall level of control, particularly when a ‘double knock’ strategy is employed.

When using a Group A product, always ensure that an appropriate adjuvant is used, through a nozzle that will not significantly alter the spray quality with the addition of the adjuvant (see table 2). Also ensure the water quality is suitable by testing for bicarbonate levels before the application.

Broadleaf sprays in crop

Fully translocated products such as the Group I herbicides should be applied with a coarse spray quality or larger at application volumes above 60 L/ha. Where a product with contact activity is used the application volume should be increased to 80 L/ha or more.

Table 2. Variation in the Dv0.5 (VMD) produced by selected low drift nozzles* operated at 3.0 bar, expressed as the standard deviation +/- from the Dv0.5 (VMD)[1] in micrometers (µm) for 3 spray solutions

Spray Solution	water	clopyralid	pinoxaden + methylated oil	Average Standard Deviation
Nozzles Tested (all nozzles were operated at 3.5 bar)	Standard Deviation + / - micrometers (µm)			
	7.33	4.69	4.45	5.49
Bellericay Bubblejet ABJ 110-015	28.62	26.01	14.52	23.05
Bellericay Bubblejet ABJ 110-02	9.60	5.11	3.54	6.08
TeeJet AITTJ60-110-02	8.40	8.72	9.78	8.97
TeeJet AIXR 110-015	5.44	10.28	9.06	8.26
TeeJet AIXR 110-02	19.63	16.40	12.80	16.28
Hypro Guardian Air 110-015	15.92	14.27	10.61	13.60
Hypro Guardian Air 110-02	6.14	8.17	8.73	7.68
Lechler IDK 120-02	4.64	6.35	4.84	5.28
Lechler IDKT 120-02	6.32	8.23	4.29	6.28
Hardi Minidrift MD-110-02	4.16	3.73	3.10	3.66
Hardi Minidrift Duo-110-02	5.23	2.30	3.53	3.68
TeeJet TTI 110-015	13.04	10.51	14.04	12.53
TeeJet TTI 110-02	5.39	8.71	12.25	8.78
Teejet TTJ60-110-02	41.71	11.69	5.83	19.74
Hypro ULD 120-015	7.75	14.11	8.54	10.13
Hypro ULD 120-02	7.63	3.39	3.89	4.97

[1]Dv0.5 or VMD is the droplet size (diameter in micrometers or µm) at which half of the spray volume produced by the nozzle will exist as droplets smaller than this size, and the other half will exist as dropets larger than this size.

*note the range of nozzles listed in this table does not include all of the nozzles tested by J Connor Ferguson

Late season applications into dense canopies

Late season fungicide and insecticide applications, along with pre-harvest desiccation, typically require that the droplets are able to penetrate into the canopy. The size of the canopy and the architecture of the plants will greatly influence how far droplets can penetrate into the canopy.

Leaf type, leaf shape and leaf surface all affect how well droplets will be retained. Droplet retention on most cereals and large grass type crops will be improved by using a medium spray quality (where permitted on label), however penetration through a canopy may be increased using a coarse spray quality. Droplet retention on many broadleaf crops may allow for good retention when using coarse spray qualities.

With a standard boom sprayer there are only a limited number of things the operator can do to potentially improve the penetration into the canopy, those include:

- Reducing the spraying speed
- Increasing the application volume
- Manipulating the spray quality, and
- Utilise a narrower nozzle spacing

To make a greater impact on penetration into the canopy generally requires the use air assistance to help transport droplets into the canopy. While the addition of air into the equation can add another layer of complexity to the sprayer setup, it can also provide large improvements in canopy penetration when correctly setup and adjusted.

To assess which variations in the sprayer setup and operating parameters can actually improve the penetration into dense canopies, useful tools include water sensitive paper (WSP) and the SNAPCARD app, which can help the operator to determine where improvements are being made.

Consider assessing spray deposits to improve your spray coverage

Using tools such as water sensitive paper will allow the operator to look at where the droplets are landing and to compare various sprayer setups to see which ones provide the best coverage.

Often it is difficult to see small improvements in coverage. A tool that can measure the level of spray deposit can assist when trying to evaluate changes. The SNAPCARD app allows spray operators to measure the spray deposits onto water sensitive paper by indicating a 'percent coverage.' Taking regular measurements and recording this information allows for continual improvements in the sprayer setup for different types of spray applications.

Further reading

https://grdc.com.au/GrowNotesSprayApplication

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Low levels of Fusarium head blight in 2016 – where did it come from and what does it mean?

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Key words

Crown rot, Fusarium head blight, seedling blight, seed infection, melanism

GRDC codes

DAN00176

Take home messages

- Low levels of Fusarium head blight (FHB) observed in central and northern NSW in 2016 were predominantly caused by *Fusarium pseudograminearum* (*Fp*).
- This was the crown rot fungus (*Fp*) reminding growers that it does not disappear in a wet season.
- FHB infection caused by *Fp* has reduced risk for mycotoxin accumulation in infected grain but could have detrimental impacts on crop establishment if retained for planting in 2017.
- Planting *Fusarium* infected grain can also introduce seed-borne crown rot infection into clean paddocks, undoing rotational benefits associated with growing non-host crops.
- Growers are urged to test both their crown rot inoculum levels in paddocks prior to sowing and ensure their 2017 planting seed has no or low levels of *Fusarium* infection if they observed FHB in 2016, especially if considering durum production.

Background

Above average rainfall was experienced in many parts of northern NSW in the 2016 winter cropping season. While this was great for increasing crop yield, unfortunately these conditions also favoured the development of a range of diseases. Of particular concern were low levels of head infections in durum and bread wheat crops and other concerns around black point and weather damaged grain. Fortunately these issues had a relatively low incidence in crops and were quite restricted in their distribution across the cropping region. However, during the actual flowering and heading stage of crop development misdiagnosis and associated unnecessary panic was not uncommon.

A survey of symptomatic heads and grain samples was conducted in 2016 to determine the various causes and to address concerns around Fusarium head blight (FHB) infections. FHB relates to the symptoms of head infection resulting in premature ripening of infected spikelets, generally caused by two fungi *F. graminearum* or *F. pseudograminearum*, following wet weather during flowering and/or grain-fill. White grain disorder, caused by *Eutiarosporella* spp. (formerly *Botryosphaeria*), produces similar visual symptoms that are not easily distinguished from FHB. These diseases are not uncommon in the northern grains region with the last widespread occurrence in northern NSW and southern Qld in 2010. NSW DPI conducted a similar study in 2010 with implications for mycotoxin production based on identification of causal species, issues with sowing infected grain and potential role of seed treatments presented at previous GRDC Updates. Some of this information will be covered in this paper as it is still very relevant to the situation that occurred in 2016.

Research in 2016

NSW DPI with the assistance of agronomists and growers conducted a survey of wheat crops with visible head infections or with discoloured white grains at harvest to determine the causal fungi. Head and grain symptoms were consistent with Fusarium head blight or white grain disorder so

laboratory techniques were concentrated on recovery of these causal pathogens. Grain samples from seed sources targeted for sowing in 2017 were also assessed to determine the incidence of *Fusarium* and/or *Eutiarosporella* infection. Representative isolates collected from symptomatic heads or grain were identified to the species level using molecular techniques. Determining the exact causal pathogen has potential consequences for the risk of mycotoxin contamination and end use of affected grain.

What did we find and what does it mean?

Shot and sprung wheat

There were only limited reports of shot and sprung grain from the 2016 harvest in northern NSW. Damaged grain is usually downgraded to feed quality with no associated mycotoxin risks unless the grain goes mouldy which can occur if moisture content is above 12.5%. Feed value of shot and sprung grain can be reduced with bulk density being a good guide. Generally wheat with a bulk density <70 kg/hL, barley <60 kg/hL and triticale <67 kg/hL has around 60% the metabolised energy of good grain (Nourishing News, 2010).

Black point

Black point, which appears as a dark discolouration at the germ end of grain, is favoured by high humidity during the late stages of grain development. Hence, there were some instances in 2016 crops. Debate continues as to the actual cause of black point but definitive Australian research demonstrated that it is a physiological process related to the production of enzymes and not due to fungal infection. Either way, grain affected by black point is usually downgraded once above receival standards but is not associated with the production of mycotoxins as long as grain moisture content is maintained <12.5% to prevent the growth of moulds post-harvest. Black point is not desirable in durum wheat as it can result in undesired black specks in the pasta product but its impact on the quality of bread wheat is as debatable as its cause. Rees *et al.* (1984) in a study of the quality of black point affected grain stated “as the changes in quality detected were very slight, the condition had little effect on the value of the grain for bread making”.

Melanism

Initially FHB symptoms in wheat appear as small brown lesions on the glumes of infected spikelets within heads. Melanism (false- or pseudo-black chaff), is related to the overexpression of a brown pigment called melanoid under conditions of high humidity. The pigment concentrates in the glumes of wheat varieties (e.g. Suntop(Φ), Spitfire(Φ), Sunmate(Φ), Trojan(Φ)) which carry the stem rust resistance gene Sr2 and was widespread in 2016. Unfortunately this physiological condition was sometimes misdiagnosed as early FHB infections. Melanism occurs on all glumes within a head and only discolours one side of the rachis (stem in head) so that when viewing from one side only every second segment is brown. Melanism can also cause the stem directly below the head to go brown and can even discolour stems in some varieties, with browning always extending downwards from a node. Initial FHB infections usually occur as point infections on one or two glumes within a head and when the infection progresses to the rachis it produces browning on both sides at that point. *Fusarium* infection can cause browning of the stem but crown rot symptoms generally extend up the stem from the tiller bases and when node infections do occur the browning always extends upwards not downwards from a node as with melanism.

Head infections

Head or grain samples were collected from a total of 80 paddocks from central and northern NSW in 2016 and causal pathogens identified to species. In 66% of cases FHB was caused by *F. pseudograminearum* (*Fp*) only, 4% by *Fusarium graminearum* (*Fg*) only, 19% were a mixed

infection of *Fp* + *Fg* and 1% (one paddock) had a mixed infection from *Fp* and *F. cerealis* (*Fcer*)(Figure 1). A total of 4% paddocks had white grain disorder with recovery of *Eutiarosporella* (*Eut*) only with a further 4% having a mixed infection of *Fp* + *Eut* and 2% (2 paddocks) having mixed infection by *Fp* + *Fg* + *Eut* (Figure 1). Given the increased susceptibility of durum wheat to *Fusarium* infection, both FHB and crown rot, there was a slight dominance of samples coming from durum crops but plenty of infected bread wheat samples were also received.

Fusarium pseudograminearum (*Fp*) is the main species usually causing crown rot. Hence it appears that the low levels of FHB in 66% of paddocks surveyed in 2016 have come from *Fp* producing spore masses (macroconidia) on the lowest nodes of tillers infected with crown rot. Rain-splash then disperses these spores up the canopy to infect heads at flowering and cause low levels of FHB symptoms in a wet year.

There are two other main species of *Fusarium* which can cause FHB, being *F. graminearum* (*Fg*) and *F. culmorum* (*Fc*). *Fg* has more commonly been associated with FHB in the northern region and has a life stage (perithecia) which is produced on maize, sorghum, grass weeds and winter cereals. The perithecia are full of smaller spores called ascospores which are air-borne and hence more easily dispersed into wheat heads during flowering. Fortunately, *Fp* does not readily produce perithecia in the paddock and does not host on maize and sorghum. A total of 23% of paddocks had FHB infection associated with *Fg* which was most commonly in a mixed infection with *Fp.* Although *Fc* was not identified in any of the samples another species *F. cerealis* was identified in a durum sample from Terry Hie Hie in a mixed infection with *Fp* (Figure 1).

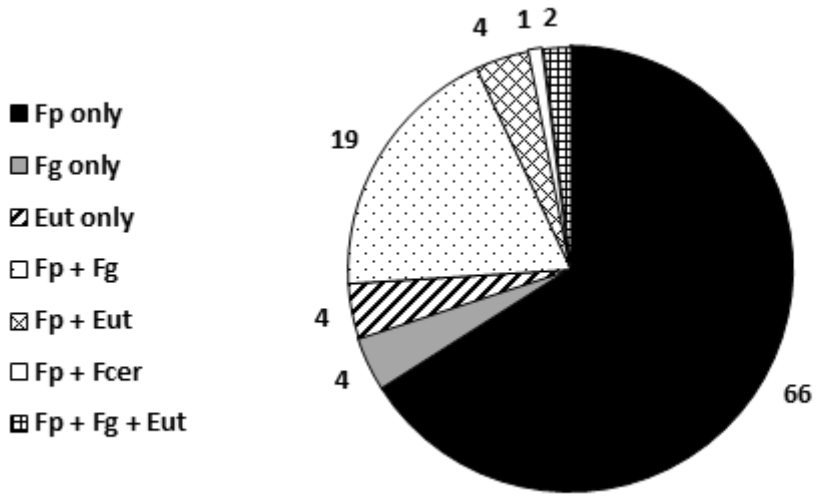

Figure 1. Fungal pathogens associated with head and grain infections in 2016
Fp = Fusarium pseudograminearum, Fg = F. graminearum, Eut = Eutiarosporella, Fcer = F. cerealis

Why is identifying the exact causal pathogen important?

In wetter seasons with frequent rainfall during flowering, which favour FHB infection, if it is *Fp* causing the infection then the incidence is usually considerably lower than if *Fg* is the causal pathogen. This is due to that lack of an air-borne spore stage (ascospore) with *Fp*, with prolonged wet weather required for *Fp* to first produce spore masses (macroconidia) around lower nodes on infected stems. The macroconidia, although still microscopic, are considerably heavier than ascospores hence they require splash dispersal to infect heads during flowering. This limits the dispersal of *Fp.* In contrast the ascospore stage in the life cycle of *Fg* is not as reliant on moisture for initial maturation of perithecia which contain the ascopsores. Rainfall during flowering is simply then required for the ascospores to be released, which then more readily are dispersed into heads during

flowering by wind. This was consistent with the very low incidence of infected heads in paddocks in 2016 with most having well below 1% of heads visually infected.

Identification to species also has implications for potential mycotoxin issues within infected grain. The main mycotoxins produced by *Fusarium* are deoxynivalenol (DON) and nivalenol (NIV), with NIV being around 10 times more toxic than DON. DON is commonly called vomitoxin in the USA, with regulated limits of 1 ppm (1 mg/kg) in grain for human consumption, 5 ppm for pig feed and 10 ppm for beef/sheep/poultry feed. With *Fg,* DON levels are closely linked to the incidence of visually infected white and pink grains at harvest as mycotoxins are concentrated in these damaged seeds (Sinha and Savard, 1997). However, grain infected with *Fp* has been shown to accumulate much lower mycotoxin levels than that infected with *Fg* under laboratory conditions (Blaney and Dodman, 2002). This is supported by analysis of field samples from a previous occurrence of FHB in Australia in 1984 with Burgess *et al.* (1987) finding that grain with 38% *Fp* infection only accumulated 0.6 ppm of DON. There are also two different forms (chemotypes) of DON, with 3ADON being half as toxic as the 15ADON form. Similar research NSW DPI conducted following an FHB outbreak in northern NSW and southern Qld in 2010 determined that 92% of 137 *Fp* isolates examined were the 3ADON chemotype, 1.5% were 15ADON, 6.5% were 15 + 3ADON and none were NIV producers. In contrast 93% of the 88 *Fg* isolates examined were 15ADON, 3.5% were 3ADON and 3.5% were the NIV chemotype. Hence, determining which species of *Fusarium* is causing FHB is important as *Fg* generally produces larger quantities of more toxic forms of mycotoxins (NIV and 15ADON). Conversely, *Fp*, the main cause of FHB in 2010 and again in 2016 in this region, produces considerably lower quantities of a less toxic form of DON (3ADON) only.

Eutiarosporella spp. also cause a head infection with symptoms appearing as premature bleaching of spikelets and production of white grains. These symptoms are hard to distinguish from FHB. However, it has been shown that there are no mycotoxins associated with this pathogen and that grain infected with *Eutiarosporella* caused no issues when fed to weaner pigs for four weeks (Kopinski and Blaney, 2010). Hence, distinguishing *Eutiarosporella* infection from FHB has important consequences for the potential end use of affected grain.

Are there issues of retaining infected seed for sowing in 2017?

The issue with grain infection by *Fusarium* is that if it is sown the next year it can cause seedling death which reduces emergence. Crown rot infection can also be introduced to the base of surviving plants with infected grain also being an inoculum source for the infection of seedlings arising from uninfected grain. Grain infection with *Fusarium* only occurs as a result of FHB, which is favoured by wet conditions during flowering. Crown rot alone cannot directly result in grain infection, as the fungus does not grow up the entire stem and into heads within a season.

Additional trial work at Tamworth in 2011 investigated the effect of grain infection with *Fusarium* on emergence, and causing crown rot infection in surviving plants (seed-borne crown rot infection). Four seed lots naturally infected with varying levels of *Fusarium* (19 to 73%) during an outbreak of FHB in 2010 were used in the study.

Grain infected with *Fusarium* had lower emergence (only 15 to 55%) as it caused severe infection of the seedlings and many died, which is commonly called seedling blight. However, the trial also showed that plants which survived past the seedling-blight stage had also been infected with high levels of crown rot (average 35%). Seed-borne crown rot affects yield in the current crop and introduces infected stubble back into the paddock. Sowing *Fusarium* infected seed, therefore, undoes any break-crop benefits that may have been obtained from growing non-host crops (such as chickpea, canola, faba bean, sorghum) in the previous season.

Some seed treatments were shown to improve emergence of *Fusarium* infected grain by 10 to 30%, but had limited effect on reducing levels of seed-borne crown rot in surviving plants. Ideally growers should plant wheat seed that is free of *Fusarium* infection by targeting crops which were not

infected with FHB in 2016 as their seed sources for 2017 plantings. Grain infected with FHB is usually white and, if prolonged wet conditions occurred during grain-fill, infected grains will take on a pink appearance. However, it should be noted that if any white or pink grains are evident, then the levels of *Fusarium* infection can be significantly higher than what may be indicated by visual inspection. This is because FHB infections that occur later during grain-fill may not cause any visual discolouration of the seed.

Implications

The low levels of FHB which occurred in bread wheat and durum crops across central and northern NSW in 2016 was predominantly related to infection by *Fp.* These infections arose from spore masses produced around lower nodes of tillers infected with crown rot which were then rain-splashed into heads during flowering. Mild conditions during Spring prevents the expression of crown rot as whiteheads. Consequently, crown rot infections often go unnoticed in wetter years. The low levels of FHB evident in 2016 could be viewed as the crown rot fungus (*Fp*) reminding growers that it does not go away in a wet season. Fortunately, the generally low incidence of FHB infection only resulted in a few instances where issues with the quality of harvested grain occurred in 2016. Hence, the overall economic impact of FHB was relatively minor in 2016. However, if Spring conditions in 2016 had been more stressed with limited rainfall and warmer temperatures during grain filling, then significant and widespread losses to crown rot are likely to have occurred. Growers need to not be complacent about potential crown rot inoculum levels leading into 2017. Avoid sowing winter cereals into paddocks which had FHB in 2016 as they are likely to represent a high risk for crown rot infection in 2017. All durum wheat varieties have increased susceptibility to *Fusarium* infection, both FHB and crown rot, hence durum production should be targeted to low risk paddocks preferably based on stubble or PreDicta B testing.

Growers who noticed or suspect that they had FHB or white grain disorder in 2016 should get their planting seed tested to determine infection levels prior to sowing in 2017. This information can be used to guide appropriate seed treatment options and to source cleaner seed with lower infection levels if required. This should be the preferred option compared to sowing seed of unknown *Fusarium* levels, which if moderate will result in poor establishment and introduce significant crown rot levels into paddocks. This will compromise rotational benefits that may have been achieved by growing a non-host crop in 2016.

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

Evaluation of fungicide management strategies to control spot-form of net blotch in barley

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Key words

Systiva®, scald, yield, green leaf retention, SFNB, fungicide management

GRDC codes

DAN00176, GOA00002

Take home messages

- Spot-form of net blotch (SFNB) caused at least 18-21% yield loss in the susceptible barley varieties La Trobe and Spartacus CL in trials conducted at Tamworth and Dubbo in 2016. Note Dubbo also had another leaf disease, scald develop late in the season.
- Foliar fungicides provided effective suppression of SFNB + scald with associated yield benefits when applied at both GS31 and GS49.
- The seed treatment Systiva® provided useful levels of SFNB suppression post GS49 under moderate disease pressure at Tamworth but activity appeared to have waned by this growth stage under higher disease pressure at Dubbo.
- Systiva® basically had similar efficacy to the GS31 application of foliar fungicides when both strategies were backed up by a second foliar application at GS49.
- Product Z, an experimental foliar fungicide, appears to have improved SFNB activity compared to Amistar Xtra® which was then slightly better than Tilt®250 in these experiments.
- Barley growers are still urged to use integrated disease management (IDM) strategies to limit losses from SFNB and scald, with fungicides being only one component. IDM of barley leaf diseases will reduce disease pressure and the reliance on fungicides as the sole management tool but importantly also delays the development of resistance to these valuable chemical options.

Background

Spot-form of net blotch (SFNB), caused by the fungus *Pyrenophora teres*, is a common foliar disease of barley in the northern grains region. The pathogen survives between seasons in barley stubble so risk is elevated with both stubble retention and barley-on-barley rotations. Barley grass can also be an inoculum source. SFNB lesions reduce green leaf area (photosynthetic area) which can reduce both yield and grain quality. Losses to SFNB are most likely in wet seasons which favour infection and when greater than 10% infection occurs on the top four barley leaves during grain filling (Jayasena *et al.* 2007).

Avoiding barley-on-barley rotations, growing varieties with improved levels of resistance and application of foliar fungicides are currently the most effective management options for limiting losses to SFNB. Unfortunately, many of the common barley varieties grown in the northern grains region and recent releases have limited levels of resistance to SFNB so there is a tendency towards reliance on foliar fungicides in wetter seasons. A new fungicide seed treatment, Systiva® (fluxapyroxad) was recently registered by BASF for the control of SFNB but there is limited data from the northern grains region. Growers in the region were also interested in the relative efficacy of some of the registered foliar fungicide options against SFNB and a new Bayer CropScience fungicide (Product Z) which is in the advanced stages of evaluation and registration.

Research in 2016

Two replicated experiments were conducted in 2016 with one site at Tamworth and the second near Dubbo. The Dubbo site was established into standing stubble of a SFNB susceptible (cv. Hindmarsh♁) barley crop grown in 2015 whilst the Tamworth site was inoculated at the 2-3 leaf growth stage with a low level (100 kg/ha) of locally sourced infected cv. Urambie♁ stubble.

Two SFNB susceptible barley varieties La Trobe♁ and Spartacus CL♁ were used in both experiments at a target plant population of 100 plants/m^2 with seed treatments evaluated being:

1. Dividend M® (difenoconazole 92 g/L + metalaxyl-M 23 g/L) at 260 mL/100 kg seed
2. Systiva® (fluxapyroxad 333 g/L) at 150 mL/100 kg seed

Dividend M® is NOT registered for the control of SFNB but was included to represent a commonly used seed treatment for bunt and smut control and as the base seed treatment for evaluating the efficacy of foliar fungicides. All seed was further treated with Emerge® (imidacloprid at 240 mL/100 kg seed) to prevent early aphid feeding and the potential transmission of Barley Yellow Dwarf Virus (BYDV) compromising the experiments. The experiment at Dubbo was sown on the 20th May whilst the Tamworth trial was sown on the 16th June 2016.

Foliar fungicide treatments and application timings were:

1. Nil control where no foliar fungicide was applied
2. Tilt®250 (propiconazole at 500 mL/ha) applied at GS31
3. Amistar Xtra® (azoxystrobin + cyproconazole) applied at GS31
4. Product Z (experimental) applied at GS31
5. Tilt®250 applied at GS31 + GS49
6. Amistar Xtra® applied at GS31 + GS49
7. Product Z applied at GS31 + GS49

In addition the efficacy of a fungicide management strategy using Systiva® for early SFNB control in combination with a later (GS49) application of each of these three foliar fungicides was investigated. The full treatment combinations examined are outlined in Table 1 with four replicates of each treatment in the Dubbo experiment and six at Tamworth. The GS31 application of foliar fungicides occurred on the 9th August at Dubbo and 30th August at Tamworth; whilst the GS49 treatments were applied at Dubbo on the 13th September and at Tamworth on the 27th September.

Visual assessments of the severity of SFNB (and scald at Dubbo) were recorded after GS49 for each plot on a 0-10 scale related to the estimated leaf area infected with lesions where 0 = no lesion and 10 = 100% of leaf area infected. At each assessment the top three leaves and the bottom of the canopy (lower leaves) were scored separately. The retention of green leaf area (GLR) within the whole canopy was also visually assessed in each plot late in the season on a 0-10 scale, where 0 = no remaining green leaves and 10 = 100% of canopy still green. Both experiments were harvested using plot headers and grain samples retained for quality assessments which were unfortunately not available at the time of writing this paper.

Results

Seasonal conditions were very conducive to the development of SFNB at both sites in 2016 with frequent rainfall events and mild temperatures through Spring. Although La Trobe is rated susceptible (S) to SFNB whilst Spartacus is rated susceptible-very susceptible (S-VS) this difference in resistance level did not result in any signifcant interaction between variety and fungicide treatments at either site. Hence, throughout this paper results are presented as the average of these two SFNB and scald suscpetible barley varieties.

Tamworth 2016

The Tamworth experiment was inoculated at the seedling stage with stubble collected from SFNB suspectible barley crop (cv. Urambie) grown in 2015. This avoided any issues with establishment but created a more moderate build-up of disease pressure from SFNB throughout the season compared to the Dubbo experiment. Scald was not evident in this experiment throughout the season with SFNB being the only leaf disease observed.

The use of the seed treatment Systiva® alone provided a visual reduction in the severity of SFNB in both post GS49 assessments compared with the base seed treatment (Dividend M®) with a corresponding slight increase in GLR late in the season (Table 1). The levels of disease control and GLR provided by each of the three foliar fungicides when applied at GS31 only, were largely comparable with that achieved with the Systiva® alone treatment.

The severity of SFNB in the later assessment was further reduced with each foliar fungicide product when applied at both GS31 and then GS49, compared to application at GS31 only. Two applications of each product provided better disease control and GLR than the use of Systiva® alone with efficacy generally Product Z>Amistar Xtra®>Tilt®250 (Table 1).

Levels of disease control and GLR achieved in the second assessment (3rd November) with Systiva® were all improved when followed by a GS49 application of a foliar fungicide and were comparable to that achieved with two applications (GS31 + GS49) of each respective foliar fungicide (Table 1). Again efficacy of foliar fungicide products was generally Product Z>Amistar Xtra®>Tilt®250 when applied at GS49 following seed treatment with Systiva®.

Table 1. Effect of fungicide treatments on the severity of SFNB in the whole canopy in October, in the bottom and top of barley canopies in November and green leaf retention scores – Tamworth 2016

Seed treatment	In-crop fungicide	Score 7.10.16[A]		Bottom 3.11.16[B]		Top 3.11.16[B]		GLR 3.11.16[B]	
Dividend M	Nil	5.6	f	9.1	g	7.3	h	2.0	h
	Tilt GS31	3.8	e	7.8	f	5.6	g	3.0	g
	Amistar Xtra GS31	2.3	b	7.2	ef	4.7	ef	3.7	def
	Product Z GS31	2.5	bc	6.9	e	4.3	e	3.8	de
	Tilt GS31 + GS49	3.4	de	5.1	d	3.0	d	4.4	c
	Amistar Xtra GS31 + GS49	2.3	b	3.1	bc	1.6	bc	5.3	b
	Product Z GS31 + GS49	1.4	a	1.8	a	0.8	a	7.0	a
Systiva	Nil	3.0	cd	7.5	ef	4.9	ef	3.2	efg
	Tilt GS49	3.0	cd	5.3	d	2.8	d	4.2	cd
	Amistar Xtra GS49	3.0	cd	3.4	c	1.8	c	5.8	b
	Product Z GS49	2.6	bc	2.5	ab	1.0	ab	6.9	a

Values followed by the same letter are not significantly different (*P*=0.05).

[A]Assessment was 113 days after application (DAA) for Systiva®, 38 DAA for GS31 foliar fungicides and 10 DAA for GS49 foliar fungicides.

[B]Assessment was 140 DAA for Systiva®, 65 DAA for GS31 foliar fungicides and 37 DAA for GS49 foliar fungicides.

Yield outcomes in the Tamworth experiment predominantly corresponded to levels of SFNB control achieved and the retention of green leaf area late in the season. Although there was no “true” nil disease control in the experiment, the yield difference between the highest treatment and the nil control represented 18% yield loss (Figure 1).

The use of the seed treatment Systiva® alone provided a 7% (0.27 t/ha) yield benefit over the base seed treatment (Dividend M®) in the absence of foliar fungicide application which was equivalent to the levels of benefit provided by the GS31 only applications of each foliar fungicide product (Figure 1).

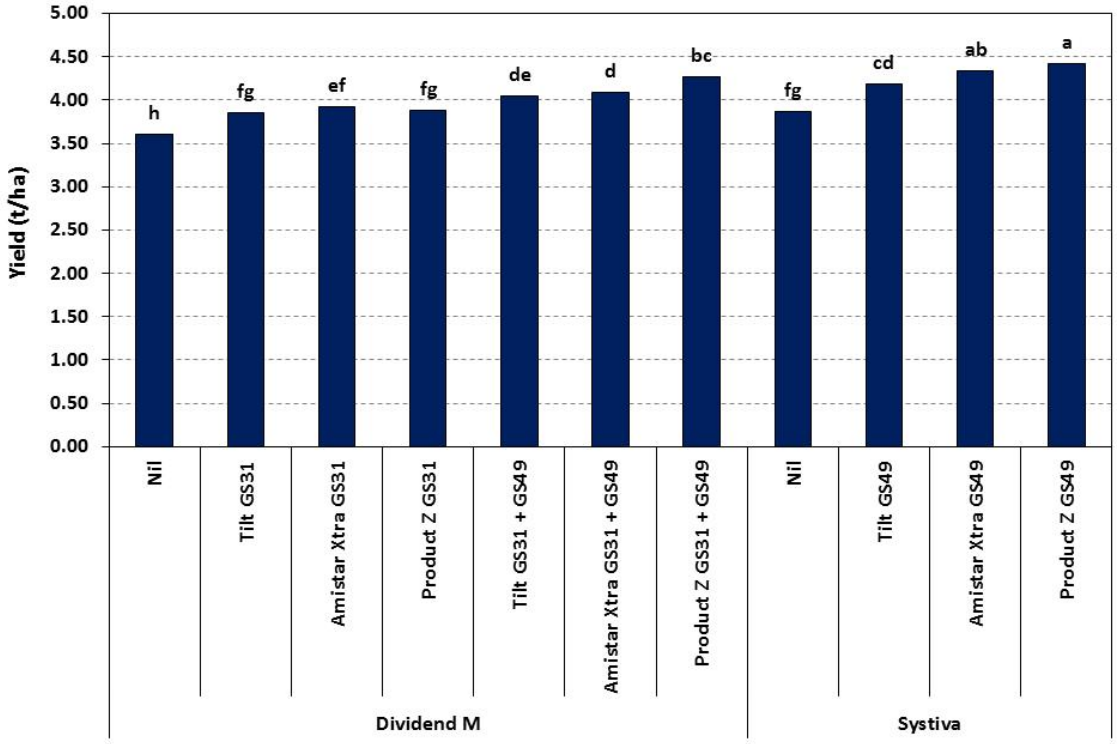

Figure 1. Effect of fungicide treatments on barley yield (average of La Trobe(1) and Spartacus CL(1)) in the presence of SFNB infection – Tamworth 2016

Bars with the same letter are not significantly different (*P*=0.05).

The yield benefit increased with two applications of each foliar fungicide product compared to the GS31 only equivalent treatment by between 12% (0.44 t/ha) with Tilt®250 up to 18% (0.66 t/ha) with Product Z at GS31 + GS49 (Figure 1). Yield benefit with two in-crop foliar applications was Product Z>Amistar Xtra® = Tilt®250.

The yield benefit associated with the seed treatment Systiva® was improved when followed by the application of a foliar fungicide at GS49. Yield in the Systiva® + Tilt®250 at GS49 treatment was equivalent to the application of Tilt®250 at both GS31 + GS49. However, with the other two foliar fungicide products the yield benefit was increased when used in combination with Systiva® compared to two applications of that product. Systiva® followed by Amistar Xtra® at GS49 provided a 0.74 t/ha (20%) yield benefit while Systiva® followed by Product Z at GS49 provided a 0.81 t/ha (23%) yield increase over the nil control treatment (Figure 1).

Dubbo 2016

The Dubbo experiment was established into a relatively heavy stubble load of a SFNB suspectible barley crop (cv. Hindmarsh) grown in 2015. Unfortunately, this resulted in patch establishment within plots but created severe disease pressure throughout the season from SFNB with another stubble-borne leaf disease, scald (*Rhynchosporium secalis*) becoming evident later in the season.

The use of the seed treatment Systiva® alone did not provide any visual reduction in the severity of SFNB in either the top or bottom of canopies compared with the base seed treatment (Dividend M)

in either post GS49 assessment (Table 2). However, Systiva® alone did provide a slight reduction in the severity of scald.

Application of the three different foliar fungicides at GS31 only provided modest reductions in the severity of SFNB in the first assessment but were less pronounced in the later assessment with no clear diffence between products. However, all three foliar fungicides when applied at GS31 roughly halved the severity of scald late in the season (Table 2). Note: Amistar Xtra is not registered for control of scald in barley.

The severity of SFNB was further reduced with each foliar fungicide product when applied at both GS31 and then GS49, with the level of control achieved with Tilt®250 and Amistar Xtra® generally being equivalent, but Product Z having improved efficacy (Table 2). Two applications of each foliar fungicide product nearly eliminated the presence of scald late in the season. Levels of disease control achieved with Systiva® were all improved when followed by a GS49 application of a foliar fungicide. However, efficacy was generally lower than that achieved with two applications (GS31 + GS49) of each respective foliar fungicides (Table 2).

Treatment trends in the retention of green leaf area (GLR) largely reflected the level of leaf disease control (SFNB + scald) achieved. In regards to foliar fungicide products, GLR was higher in treatments with two fungicide inputs with GLR generally being Product Z>Amistar Xtra®> Tilt® (Table 2).

Table 2. Impact of fungicide treatments on the severity of SFNB in the bottom and top of barley canopies at two dates, scald* severity in top of canopy and green leaf retention scores – Dubbo 2016

Seed treatment	In-crop fungicide	Bottom 28.9.16[A]	Top 28.9.16[A]	Bottom 20.10.16[B]	Top 20.10.16[B]	Scald 20.10.16[B]	GLR 27.10.16[C]
Dividend M	Nil	8.0 h	6.1 e	8.3 h	7.8 f	6.6 d	1.8 gh
	Tilt GS31	5.8 efg	4.9 cd	7.4 fgh	6.3 de	3.6 b	2.5 fg
	Amistar Xtra GS31	4.6 cd	4.0 c	7.1 efg	6.0 d	3.3 b	2.8 f
	Product Z GS31	3.8 bc	4.3 cd	8.3 h	7.0 ef	3.1 b	2.3 fgh
	Tilt GS31 + GS49	4.8 cde	3.0 b	5.5 cd	3.9 bc	0.5 a	4.5 de
	Amistar Xtra GS31 + GS49	3.5 b	2.5 b	4.6 bc	3.4 b	0.0 a	5.8 bc
	Product Z GS31 + GS49	2.4 a	1.5 a	3.1 a	1.6 a	0.0 a	6.9 a
Systiva	Nil	8.0 h	6.3 e	7.6 gh	7.3 f	5.4 c	1.5 h
	Tilt GS49	6.3 g	4.6 cd	6.4 def	4.5 c	0.3 a	4.3 e
	Amistar Xtra GS49	6.6 g	4.5 cd	6.1 de	4.4 c	0.5 a	5.1 cd
	Product Z GS49	5.1 def	3.0 b	4.1 ab	2.1 a	0.5 a	6.4 ab

Values followed by the same letter are not significantly different (*P*=0.05).

[A]Assessment was 100 days after application (DAA) for Systiva®, 50 DAA for GS31 foliar fungicides and 15 DAA for GS49 foliar fungicides.

[B]Assessment was 122 DAA for Systiva®, 72 DAA for GS31 foliar fungicides and 37 DAA for GS49 foliar fungicides.

[C]Assessment was 129 DAA for Systiva®, 79 DAA for GS31 foliar fungicides and 43 DAA for GS49 foliar fungicides.

* Amistar Xtra is not registered for control of scald in barley

Unfortunately, patchy establishment resulting from sowing into a heavy stubble load from the previous season increased the variability of yield outcomes in this experiment. Hence, differences apparent in the levels of leaf disease control and GLR did not necessarily translate into significant yield outcomes (Figure 2). Significance was only achieved at the 83% (*P*=0.17) confidence level so yield findings from this site should be interpreted with caution. Although there was no “true” nil disease control in the experiment, the yield difference between the highest treatment (Systiva® +

Product Z at GS49) and the nil control (Dividend M® with no foliar fungicide application) represented a 0.95 t/ha difference or 21% yield loss (Figure 2). Fungicide strategies that used two inputs (Systiva® + GS49 foliar fungicide or GS31 + GS49 foliar applications) provided the most consistent yield benefits over the nil control of between 0.47 t/ha (13%) with Systiva® + Tilt®250 at GS49, up to 0.95 t/ha (26%) with Systiva® + Product Z at GS40 (Figure 2).

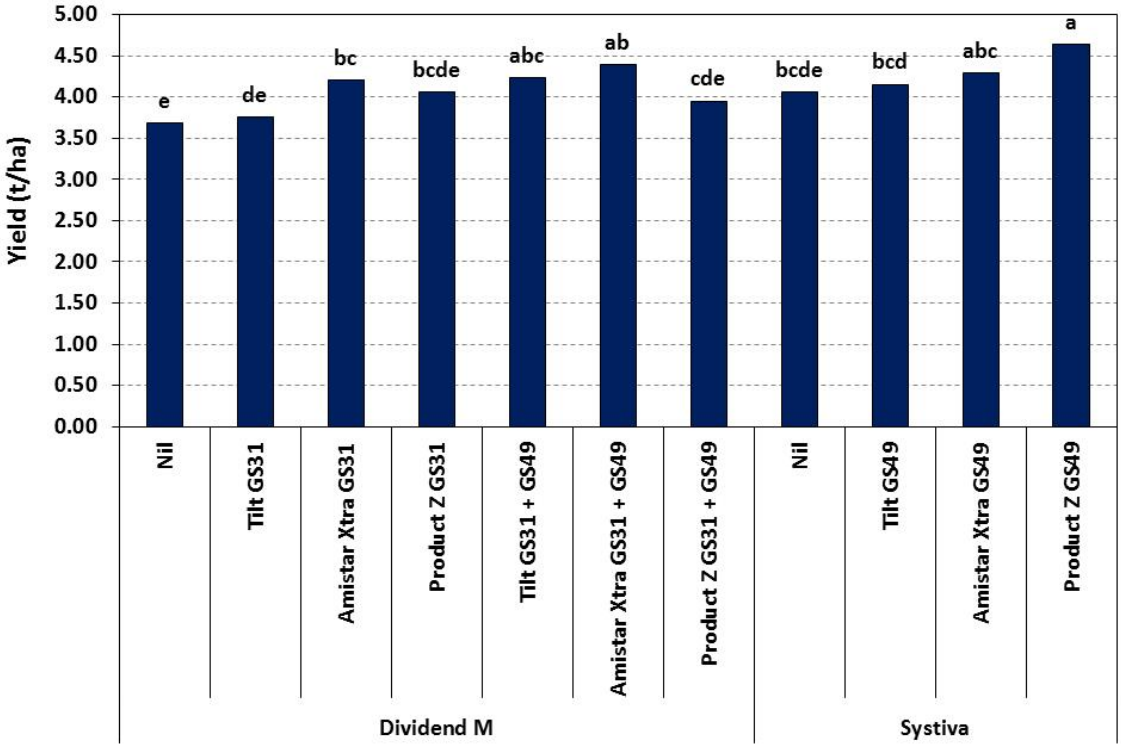

Figure 2. Effect of fungicide treatments on barley yield (average of La Trobe(1) and Spartacus CL(1)) in the presence of SFNB and scald infection – Dubbo 2016

Bars with the same letter are not significantly different (*P*=0.17).

Implications

SFNB caused significant yield losses in the susceptible barley varieties La Trobe(1) and Spartacus CL(1) at both sites under the wet seasonal conditions experienced in northern NSW in 2016. Combined application of foliar fungicides at both stem elongation (GS31) and awn emergence (GS49) provided good suppression of SFNB in both experiments and also provided effective control of scald in the Dubbo trial. While all three foliar fungicide products examined reduced the severity of SFNB, efficacy was generally Product Z>Amistar Xtra®>Tilt®250. Product Z, an experimental fungicide from Bayer CropScience appears a quite promising option for improved management of SFNB. Each of the foliar fungicides examined also provided good control of scald late in the season although Amistar Xtra not registered for the control of scald.

The seed treatment Systiva® provided useful suppression of SFNB in post GS49 assessments under moderate disease pressure at Tamworth but activity appeared to have waned by this later growth stage under higher pressure at Dubbo. However, disease suppression was improved at both sites when combined with a foliar fungicide application at GS49. In management strategies which involved two fungicide inputs, Systiva® was competitive with GS31 foliar fungicide applications at both sites when each option was backed up by a GS49 foliar fungicide application. Both of these strategies provided significant increases in grain yield under both moderate (Tamworth) and high (Dubbo) pressure from SFNB.

Although the fungicide strategies examined in these experiments provided significant yield benefits it should be stressed that no treatment provided complete disease control. Hence, some level of yield loss is still likely to have occurred. These experiments were also either inoculated (Tamworth) or sown into a high stubble load (Dubbo) of a SFNB susceptible barley variety with only SFNB and scald susceptible varieties examined in this study. This represents a high risk scenario for the development of these stubble-borne leaf diseases and places considerable pressure on disease management strategies which rely solely on the use of fungicides and is likely to accelerate selection for fungicide resistant strains of these pathogens. Stewardship with the seed treatment Systiva® involves only using this product every second year to delay the development of resistance and under high disease pressure monitor infection levels then apply a late foliar fungicide (ideally non SDHI) beyond GS31 if needed.

The results presented here should not be interpreted as the ideal production system for barley in the northern grains region, even though significant disease suppression and yield benefits were evident. Rather growers are urged to consider an integrated approach to barley disease management incorporating rotation with non-host crops (avoid barley-on-barley), stubble management and growing varieties with improved levels of resistance to reduce disease pressure. Fungicide strategies are then placed under less pressure in terms of both control and development of resistance. Additionally the economics of planned fungicide strategies needs to be considered given the higher costing of some products and marginal returns, especially with current barley prices.

References

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Seed treatments – Systiva® performance in northern trials

Greg Platz, Lisle Snyman, Ryan Fowler, Dept of Agriculture and Fisheries

Key words

Systiva, SDHI, net blotch, spot form net blotch, seed treatment

GRDC code

DAQ00187 – National Barley Foliar Pathogens Variety Improvement Program (NBFPVIP)

Take home messages

- Systiva® is a new seed treatment fungicide registered by BASF for the control of several foliar diseases of barley, smuts in barley, bunt in wheat and suppression of Rhizoctonia root rot in both.
- Systiva gives very good control of most foliar diseases for about 8 weeks of crop life.
- One or more supplementary sprays may be required for whole of season foliar disease control.
- Systiva is registered for loose smut control in barley but is ineffective against covered smut.
- Early season disease control slows disease epidemic development and increases yields where conditions after flag leaf emergence do not favour disease development.
- In 2017, seed treatment with Systiva is likely to cost approximately $15/ha or $30/100kg of seed.
- Systiva is a Group 7 fungicide and introduces new chemistry to seed treatment. Responsible use of the product is encouraged to prevent breakdown of efficacy.

Background

Systiva® gained APVMA approval for registration as a seed treatment fungicide in 2015. The active ingredient is fluxapyroxad - a Group 7 fungicide - and the first succinate dehydrogenase inhibitor (SDHI) registered for use on cereals in Australia. The product has had extensive trialling pre-release across Australia but there has been relatively limited product development in the heavier soils of the northern region.

Reports on the efficacy of Systiva from southern Australia have been very favourable with outstanding disease control in many situations. It is reported that across 80 trials Systiva gave a positive yield benefit of 350kg/ha (Pers. comm. R. Holzknect BASF).

Foliar diseases have a propensity for rapid epidemic development from low levels of inoculum, given suitable conditions for infection and spread, with the frequency and duration of leaf wetness a major driver of epidemic development. Differences in environmental conditions between southern Australia and the northern region during late crop development may influence the benefits of early season control.

Here we report the results of replicated trials conducted in 2014 and 2016 and a farm demonstration conducted in 2016 to determine the benefits of Systiva in the control of spot form net blotch. Further work needs to be done to determine the benefits of seed treatment with Systiva in controlling other diseases.

Trial results

Hermitage 2014

A replicated trial comparing the use of fluxapyroxad as either a seed treatment and/or spray was conducted at Hermitage in 2014. Systiva (fluxapyroxad) with and without a late foliar spray was compared to a popular commercial seed treatment and combinations of current commercial foliar fungicides for the control of spot form net blotch in Shepherd barley. Foliar applications were made at growth Stages 31 (early) and 41 (late) while nil disease treatments received 4 applications of Prosaro® at 300mL/ha. (Note that the Prosaro label limits use in commercial crops to a maximum of two applications per season.) There was a moderate to heavy epidemic of spot form net blotch present for the duration of the trial.

A summary of the yield results is shown in Figure 1.

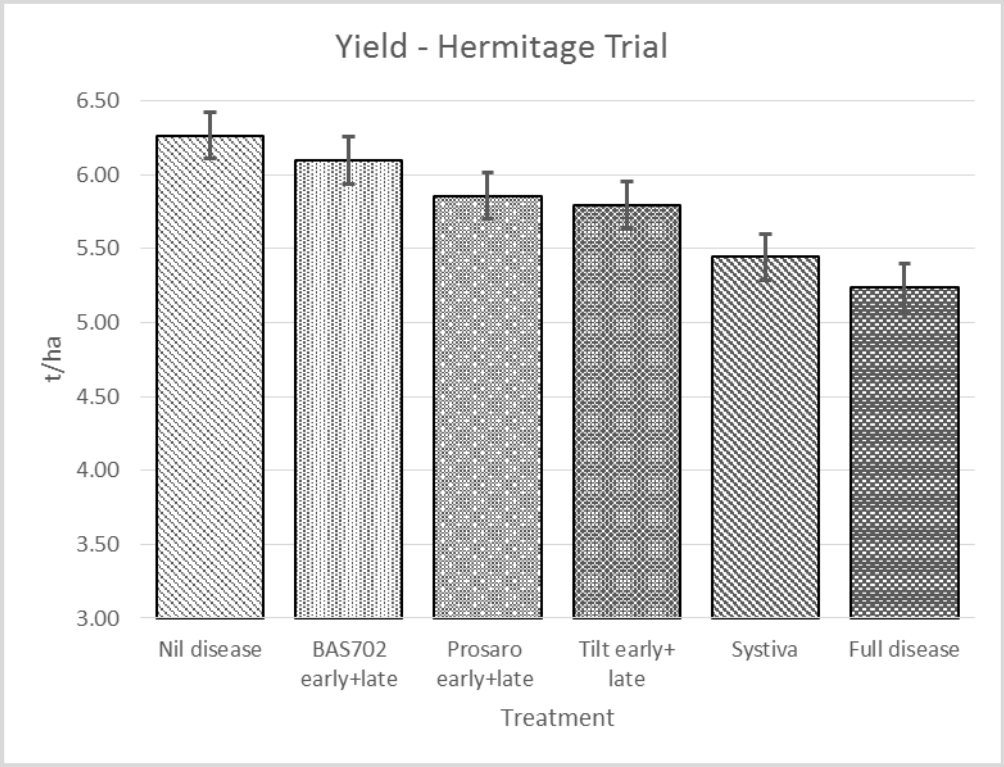

Figure 1. Yields of Shepherd barley under different fungicide treatments to control spot form of net blotch.

Four applications of Prosaro did not give absolute disease control in the Nil disease treatments; yet still resulted in a significant yield increase of 19.6% over the full disease. The yield of the Systiva treatment alone resulted in a 4% increase in yield which was not significantly different from the full disease control. However, Systiva did give positive significant differences in test weight, retention, screenings and grain size over the full disease control treatment. In a malting variety the improvement in test weight and retention would have taken the classification from feed to malting quality.

Four assessments of leaf area diseased (LAD) were conducted between 5th September (8 weeks after sowing) and 24th October. At the first assessment it was obvious that Systiva (heavy dotted line) was having an effect on disease development (Fig. 2). The three Systiva treatments had an average of 13% LAD compared to the average of the foliar spray treatments (23.5%), which at that time had not had a spray applied. However, over subsequent assessments it was obvious that the foliar sprays

were controlling the disease better than the Systiva treatment, which had %LAD levels increasing to nearer those of the full disease control (dark dotted line).

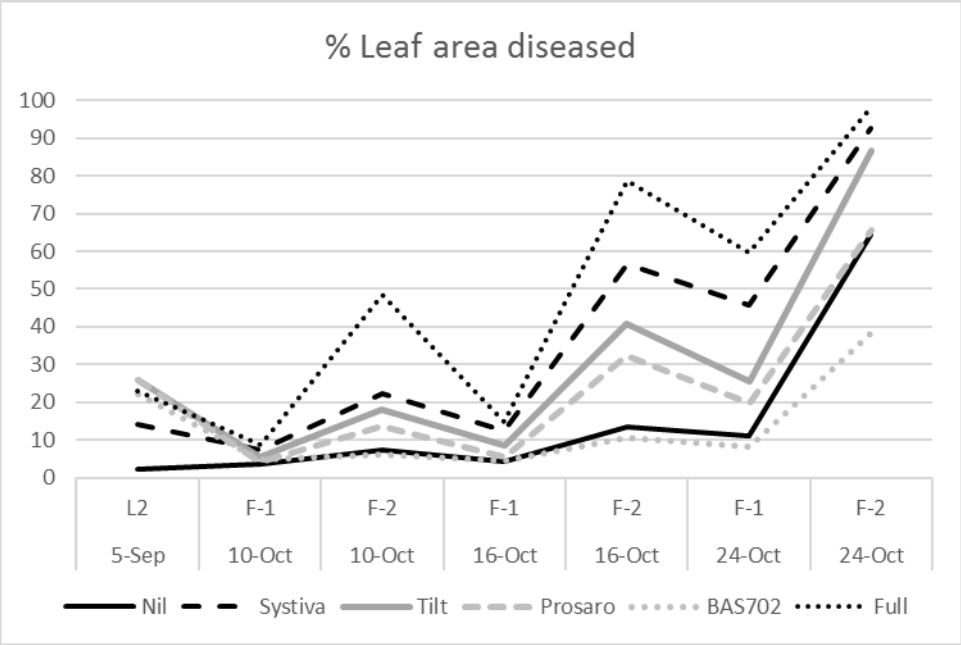

Figure 2. Percent leaf area diseased of six selected treatments.

It appeared that the effect of Systiva was waning as the crop was filling grain.

The leaves that contribute most to grain fill in barley in environments with sufficient soil moisture are the flag sheath, flag-1 and flag-2. Under conditions where epidemics of SFNB continue developing after heading, it appeared that Systiva applied without a follow-up treatment, was inferior to the application of foliar fungicides in controlling the disease and protecting grain yield.

GOA/ NSW DPI trial 2016

Systiva was evaluated for spot form net blotch control in a replicated trial conducted by Steven Simpfendorfer (NSW DPI) and Maurie Street (GOA). Data was not available in time for inclusion in this paper but is presented in the paper by Simpfendorfer and Street in these proceedings.

Farmer demonstration 2016

A broad-acre comparison of Systiva and Phoenix® (triadimenol) seed treatments for spot form net blotch control in Gairdner barley was conducted at Garah (Note: Phoenix not registered for spot form net blotch). The demonstration also incorporated stubble burnt vs unburnt. DAFQ personnel attended the field day in mid-July to compare disease control in the four treatments when the crop was at mid-tillering. Assessments were done on the last fully expanded leaf showing disease and the preceding leaf.

The lowest levels of disease were in the burnt treatment with little difference between seed treatments. The difference between the Systiva and Phoenix treatments in the stubble unburnt area was almost threefold, with Systiva having 11 and 14% LAD and Phoenix 32 and 40 % LAD (Figure 3).

It was visually obvious that the area treated with Systiva had much less disease than the Phoenix treatment.

The crop was harvested in October, but unfortunately yields were unavailable at the time of writing.

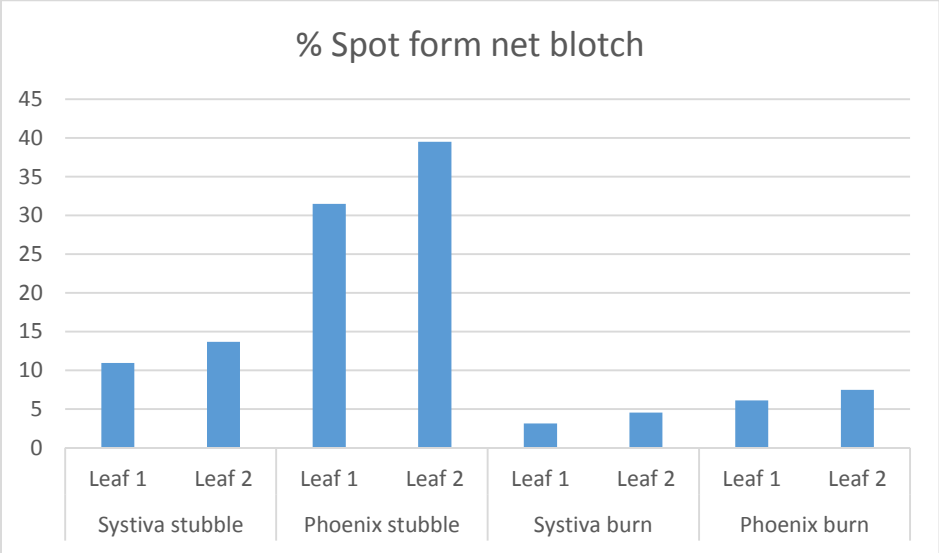

Figure 3. Percent leaf area diseased in Gairdner barley in response to seed and stubble treatments.

Conclusion

It appears that Systiva is quite effective in controlling spot form net blotch (and presumably other foliar diseases) for about 8 weeks after sowing based on results in these trials. Under conditions where disease epidemics continue to develop beyond this window, it is unlikely that Systiva will be persistent enough to provide adequate protection to the main yield contributing leaves of the flag sheath, flag-1 and flag-2. From observations and results from the limited trialling of the product in this region, it would be wise to budget at least one foliar spray in any disease management strategy using Systiva.

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The authors thank Richard Holzknect (BASF), Dr Steve Simpfendorfer (NSW DPI), Maurie Street (GOA) and Rob Long (B&W Rural) for their input into this paper.

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Leaf rust in Compass®

Lislé Snyman, Clayton Forknall and Greg Platz, Department Agriculture and Fisheries Queensland

Key words

Barley, leaf rust, resistance, yield response

GRDC code

DAW00245

Take home messages

- Compass® is very susceptible to leaf rust and crops should be closely monitored for the disease.
- Barley varieties differ in yield response to leaf rust across resistance ratings.
- Resistance ratings of current commercial varieties are available on the NVT website.
- Growing resistant varieties is the most practical and economical way of controlling barley leaf rust.
- Varieties characterised as S to VS are impacted most by disease and also contribute to inoculum increase, leading to pathogen mutations putting available resistance genes at risk.
- The use of resistant varieties forms part of a bigger disease management plan, which also includes green-bridge control, regular crop monitoring and the timely application of fungicides.

Introduction

Leaf rust of barley is widely distributed and occurs regularly in the northern region. It is considered one of the five major barley diseases in Australia and can cause significant yield loss and a reduction in grain quality (Murray & Brennan, 2009). Barley leaf rust was widespread in Queensland in 2016 on Compass and other vulnerable varieties. In most instances, timely fungicide sprays were able to avoid epidemic infection levels.

The disease is caused by the obligate parasite (*Puccinia hordei*), spreading by means of airborne spores that have the ability to travel long distances. The pathogen spreads rapidly when conditions are favourable and large areas are planted to susceptible varieties, creating favourable conditions for epidemics to develop. In the presence of a green bridge, the pathogen can survive over summer and be present at high levels early in the growing season. High inoculum levels put pressure on major resistance genes and can lead to the development of new, more virulent pathotypes.

Why the concern about Compass®?

Compass® is a high-yielding, broadly adapted, mid-season maturing variety expected to complete Barley Australia malt accreditation by March 2018. In Queensland, it is rated VS to pathotypes virulent for the *Rph3* gene. This virulence is present in all major production areas.

Compass® currently accounts for 15-20% of barley production in Australia. Due to the high yielding ability over a range of environments, the area sown to Compass® in 2016 was estimated to be approximately 20 000ha in WA, 400 000ha in SA, 120 000ha in VIC, 60 000ha in NSW and 20 000ha in QLD, totalling at 620 000ha of the barley production area (Seednet – pers. comm.). Widespread cultivation of a variety as susceptible as Compass® to barley leaf rust ensures a continuous supply of rust inoculum and contributes to the breakdown of valuable resistance genes.

Some of the major factors contributing to the barley leaf rust epidemic in Queensland in 2010 was the widespread sowings of susceptible varieties, which in turn led to an increase in the inoculum load and conditions favourable for disease development. High inoculum pressure and application of

fungicides after establishment of the disease contributed to mixed results from the application of foliar fungicides.

The area sown to Compass® (VS) is expected to increase across production areas in 2017. Large areas sown to a VS variety across a range of environments almost ensures that leaf rust will be a problem in some areas contributing to high inoculum levels causing epidemics whilst adding selection pressure on the pathogen to mutate and acquire new virulences.

Yield response curve trials

Since 2013 trials have been conducted by DAF QLD in an effort to quantify losses caused by barley leaf rust. A pilot study in 2013, on barley varieties ranging in resistance levels from MR to VS, showed the benefits of fungicide application on susceptible varieties. Results indicated that the more susceptible a variety, the more benefit can be gained by foliar fungicide application.

Following the 2013 results, more detailed trials were performed annually from 2014. The relationship between yield and disease severity was examined in six varieties, with resistance levels ranging between MR and VS. Plots were inoculated to represent infection levels ranging from nil disease (fungicide treated) to high disease levels.

After the 2014 trial, Compass® (included in S category) was clearly a VS type based on yield loss (38.5%) when compared to Grout® with a 25.1% yield loss. Similarly, the biggest yield loss (28.8%) was observed in Compass® in 2015 (Figure 1).

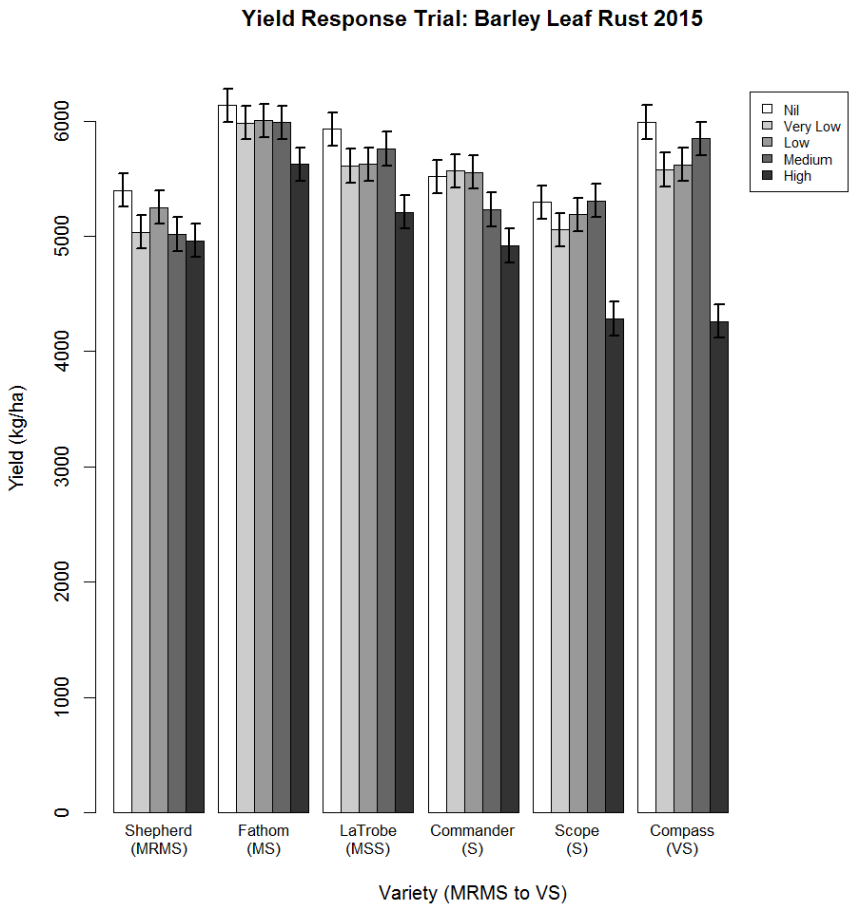

Figure 1. Yield response of barley varieties to different disease levels in 2015. (Shepherd®, Fathom®, La Trobe®, Commander®, Scope® and Compass® are all protected under the Plant Breeders Rights Act 1994.)

In 2016, yield loss of 45.6% was recorded in Compass® (VS) and 57.6% in Bass® (SVS) (Figure. 2). Yield losses in Shepherd® (MRMS) were 8.1% and 10.5% for the two years respectively and Fathom® (MS) 8.3% and 7.7%.

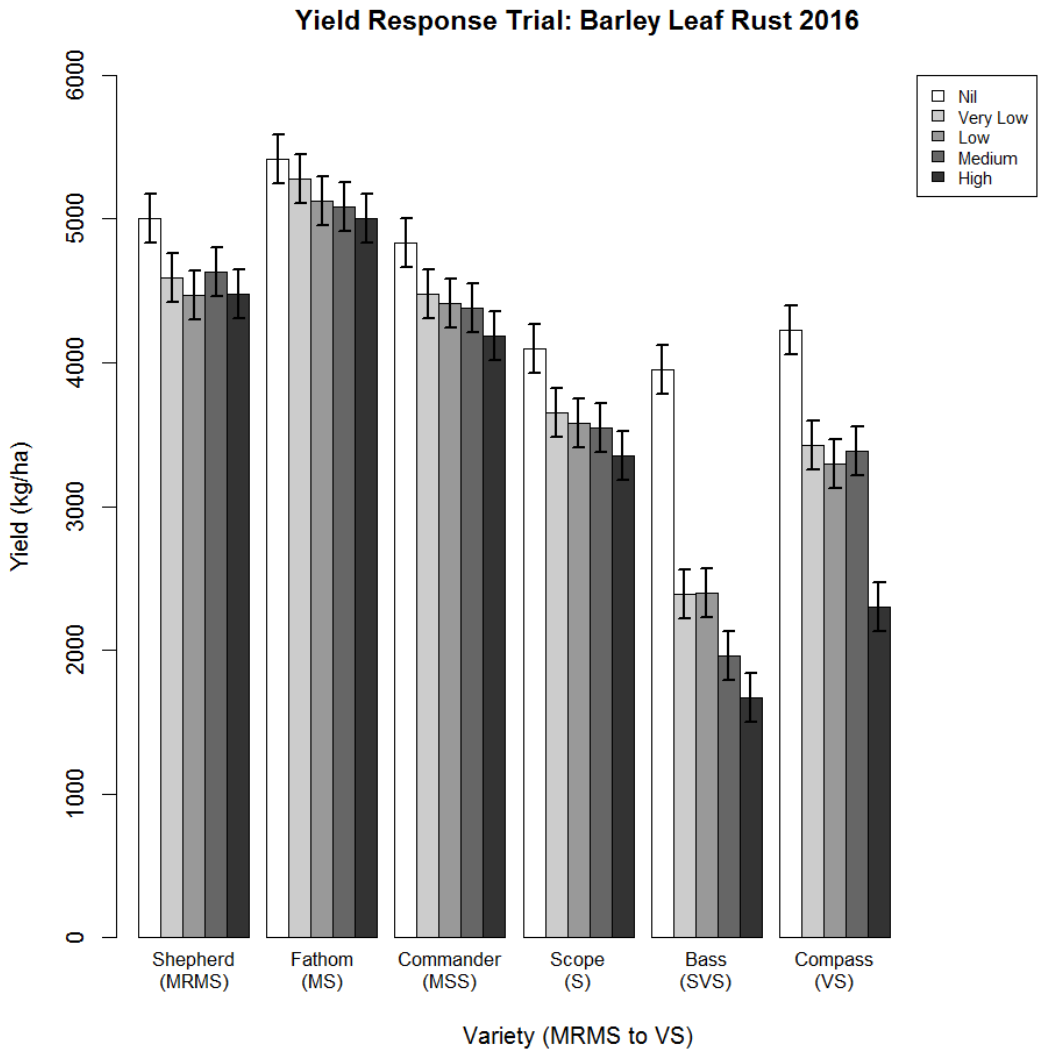

Figure 2. Yield response of barley varieties to different disease levels in 2016. (Shepherd®, Fathom®, La Trobe®, Commander®, Scope®, Bass® and Compass® are all protected under the Plant Breeders Rights Act 1994.)

Results from these trials confirmed earlier reports that barley leaf rust infection can result in quality losses. From the retention results displayed in Figure 3 it is obvious that susceptible varieties suffered huge losses in terms of quality. Retention in all six varieties were significantly better in the nil disease treatment than in all other treatments. In the varieties Commander®, Scope® and Compass®, the high disease treatment had a significantly lower retention percentage than the other diseased treatments (medium, low and very low). For the malting variety Commander®, retention percentages in all treatments were higher than 58%, whereas none of the treatments in Scope® and Bass® would be acceptable as malt quality. For Compass® only the nil treatment would qualify for malt quality when accredited. Similar observations were made with regards to other quality characteristics such as test weight.

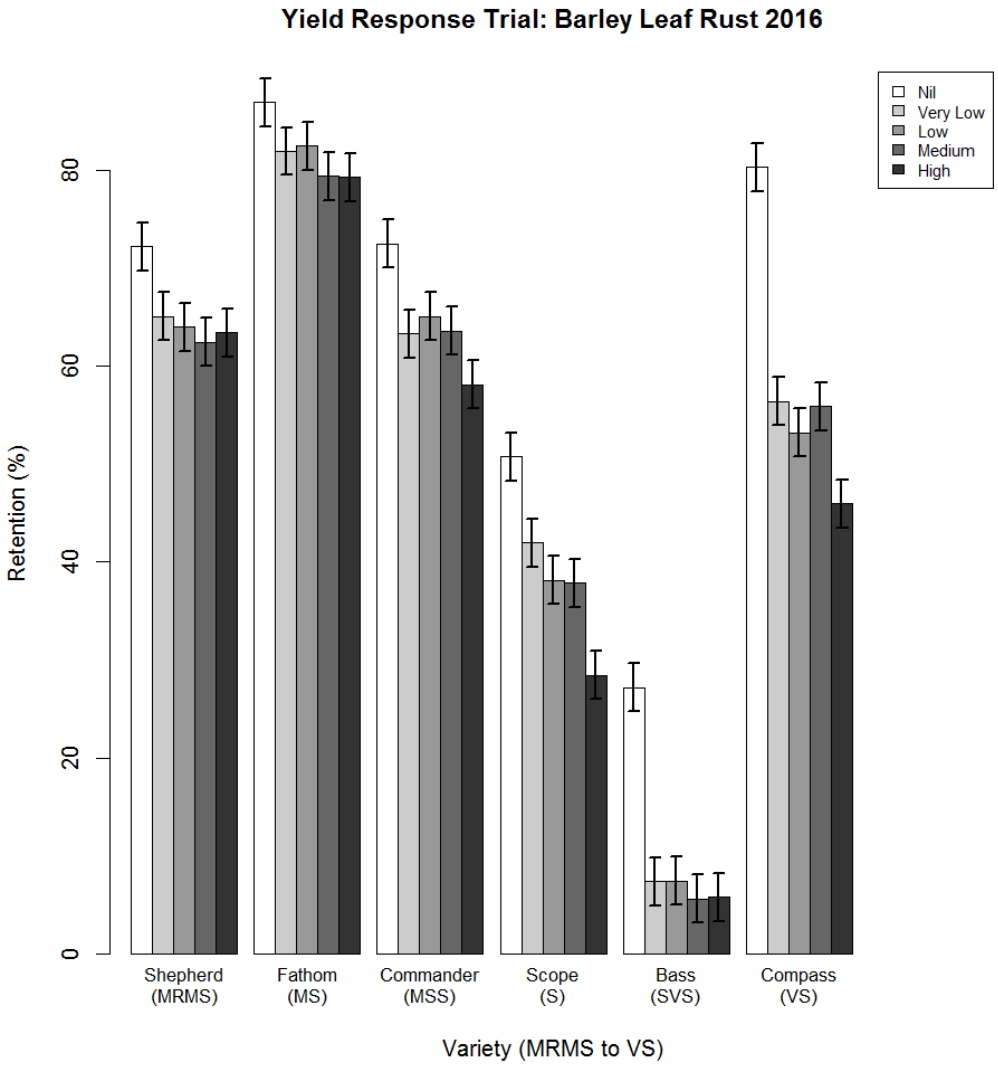

Figure 3. Response in retention percentage of barley varieties to different disease levels in 2016. (Shepherd Φ, Fathom Φ, La Trobe Φ, Commander Φ, Scope Φ, Bass Φ and Compass Φ are all protected under the Plant Breeders Rights Act 1994.)

Conclusions

Results from the yield response curve trials conducted between 2014 and 2016 indicated that disease has a significantly bigger impact on the yield and quality characteristics of varieties in the S to VS categories, than on more resistant varieties. In all three years, Compass Φ suffered significant losses ranging between 28.8% and 45.6%. The only variety tested to suffer bigger losses was Bass Φ in 2016.

Therefore it can be concluded that the more susceptible a variety, the bigger the yield and quality losses due to leaf rust. The area planted to Compass Φ is expected to increase in 2017 and with the increase in area of susceptible, especially very susceptible varieties grown, the risk of epidemics increase, particularly if conditions are favourable for disease development.

The best strategy for barley leaf rust control is to grow resistant varieties and if not, to remain vigilant with crop management decisions. It is important to ensure that there are no green bridge for the rust pathogen to over summer on. Regular crop monitoring is essential for timely fungicide control and to decide if follow-up applications are needed.

From these results it can be concluded that growing a susceptible variety such as Compass(b) increase the risk of yield and quality loss and requires dedicated effort towards persistent monitoring and decision making.

Reference

Murray, GM & Brennan GP, 2009. Estimating disease losses to the Australian barley industry. *Australasian Plant Pathology* 39, 85-96.

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(b) Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Increased levels of net form of net blotch in Commander[Φ] and Shepherd[Φ]

Ryan Fowler and Greg Platz, Dept of Agriculture and Fisheries

Key words

Barley, net form of net blotch, NFNB, disease resistance, virulence, seed treatment

GRDC code

DAQ00187 – National Barley Foliar Pathogen Variety Improvement Program (NBFPVIP)

Take home messages

- Prolonged and widespread sowing of Commander[Φ] and Shepherd[Φ] barleys has allowed net form net blotch (NFNB) to adapt to these varieties.
- Pathotypes able to infect Commander[Φ] and Shepherd[Φ], that were once rare, have increased in prevalence in recent years.
- NFNB can be spread via the sowing of infected seed that has not been treated.
- Sowing barley on barley or more specifically, sowing a variety back into stubble of that same variety, causes the disease to increase within paddocks over time.
- Environmental conditions play a major role in the development of NFNB, with wet conditions favouring infection and spread of the disease, like the spring of 2016.
- NFNB is best controlled by crop rotation, sowing of varieties with a disease rating of MS or better, treating seed prior to sowing, monitoring crops for NFNB during the season and timely application of a registered foliar fungicide before disease becomes conspicuous in an S to VS variety.

Background

Net form of net blotch is widespread throughout Australia and is found in most areas of the Northern Region. The disease persists in crop residues and infected seed between seasons. Frequent wet periods and mild temperatures favour disease development. Many different pathotypes of NFNB are present in the Northern Region and are able to infect most varieties, producing low to moderate disease symptoms on varieties rated as RMR to MSS. A very susceptible disease response occurs when a pathotype and a variety are fully compatible. NFNB has been an intermittent problem in the Northern Region, with some unusually wet years resulting in heavy epidemics on varieties such as Binalong[Φ] and Skiff in New South Wales and Gilbert and Grimmett in Queensland.

Net Form Net Blotch in the Northern Region

GRDC fund national, annual pathotype surveys of NFNB and this work is conducted under the National Barley Foliar Pathogens Variety Improvement Program from The Hermitage Research Facility. These surveys have identified at least four distinct groups of isolates - across Australia (Fig.1 and Fig. 2). Collectively, these Isolates are able to successfully infect most varieties, though the level of disease development varies depending on the isolate/variety combination (Fig. 1).

Groups are assigned by the varieties on which they show a susceptible infection type.

Group 1 isolates are highly virulent on:

- Binalong[Φ], Cowabbie[Φ], Fairview[Φ], Grimmett, Skiff, Tantangara and Yambla

Group 2 isolates are highly virulent on:

- Gilbert and Grimmett

Group 3 isolates are highly virulent on:

- Commander$^{\Phi}$, Grout$^{\Phi}$, Keel$^{\Phi}$, Mackay$^{\Phi}$, Navigator$^{\Phi}$ and Prior

Group 4 isolates are highly virulent on:

- Beecher, Maritime$^{\Phi}$ and Roe$^{\Phi}$

Shepherd$^{\Phi}$ and Granger$^{\Phi}$ and Fleet$^{\Phi}$ are susceptible to isolates that fall outside these groups; yet isolates that are virulent on Shepherd$^{\Phi}$ and Granger are avirulent on Fleet$^{\Phi}$ and vice versa.

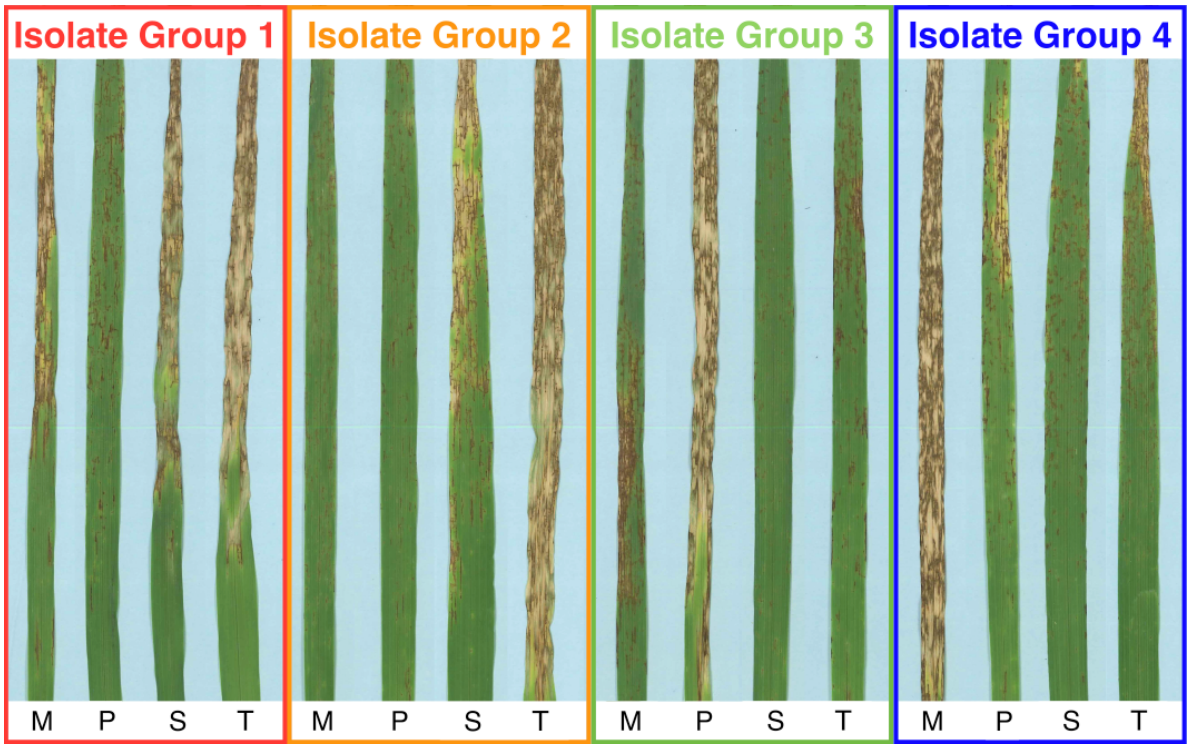

Figure 1. Disease expression of the four main isolate groups on four key varieties. M = Maritime$^{\Phi}$, P = Prior, S = Skiff and T = Tallon. Fowler *et al.* 2017.

Pathotypes from Isolate Groups 1, 2 and 3 are present in the Northern Region (Fig. 1). The most prevalent pathotypes in the Northern Region are from Isolate Group 1 (Fig. 2).

Commander$^{\Phi}$ is quite susceptible at seedling growth stages to most pathotypes, yet does expresses a useful level of adult plant resistance to the predominant pathotypes (Isolate Group 1) found in the Northern Region. However, at adult growth stages Commander$^{\Phi}$ is quite susceptible to pathotypes that attack Prior, Corvette and Mackay$^{\Phi}$ (Isolate Group 3) see Table 1. These isolates are common in Queensland and appear to be increasing in NSW (Fig. 2).

Shepherd$^{\Phi}$ is susceptible to two pathotypes that fall outside these groups.

Commander$^{\Phi}$ and Shepherd$^{\Phi}$ have been the leading malt and feed varieties in the “old” Northern Region over the past five years. Large scale plantings have placed great selection pressure on the pathogen, resulting in increased virulence for their resistance profiles which has led to greater incidence and severity of NFNB in crops of these varieties. Selection pressures that have caused an increase in disease on Commander$^{\Phi}$ and Shepherd include:

- Adaptation of the pathogen for increased virulence
    - Sowing any one variety over a prolonged period places selection pressure on the pathogen to adapt to that variety for its own survival and reproduction. Net blotches are sexually reproducing organisms and progeny of crosses that carry increased virulence for a variety are likely to increase over time. This means that virulence genes are gradually accumulated allowing the pathogen to better infect and colonise plants of that variety.
- Increased prevalence of existing or rare pathotypes
    - Pathotypes that are highly virulent on Commander[ф] are common in Queensland and higher disease levels observed in NSW suggest that this pathotype is increasing farther south. See "Prior" pathotype in Table 1. The continued cultivation of Commander provides a selective host for Prior virulent pathotypes to increase.
    - Two pathotypes that are highly virulent on Shepherd[ф] are present in Queensland.
        - Shep 1 was detected in 1995 and has increased in prevalence in recent years (Table 1)
        - Shep 2 was detected in 2015 and is now widespread over the Darling Downs. This pathotype has subtle differences from Shep 1 (Table 1)

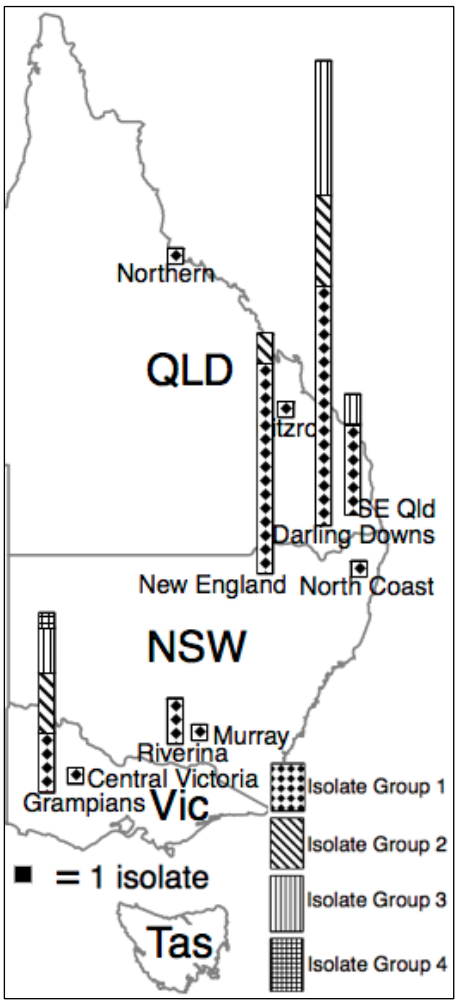

Figure 2. Distribution of four NFNB isolate groups in eastern Australia. Fowler *et al*. 2017.

Table 1. Seedling response of 15 barley genotypes to 10 NFNB isolates collected from Compass[b] and Shepherd[b] in 2016 and three routine screening isolates (NB50, NB73, NB85) used at Hermitage Research Facility. Scores ≥6.5 indicate a susceptible response.

Isolate	**NB50**	**NB73**	**#16031a**	**#16051NFa**	**#16033a**	**#16083a**	**#16027a**	**#16025a**	**#16043a**	**#16041a**	**#16026a**	**#16024a**	**NB85**
Pathotype	Skiff	Shep 1	Shep 1	Shep 1	Shep 2	Shep 2	Shep 2	Shep 2	Comp-Nav	Comp-Nav	Comp-Nav	Comp-Nav	Prior
Test GS	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling	Seedling
Collected	26/7/94	16/6/95	6/9/16	16/9/16	7/9/16	24/9/16	2/9/16	2/9/16	13/9/16	8/9/16	2/9/16	5/9/16	22/9/95
State	Qld	Qld	Qld	Qld	Qld	Qld	Qld	Qld	Qld	SA	NSW	NSW	Qld
Location	Gatton	Tansey	Junabee	Warrill View	Yangan	Mt Colliery	Pittsworth	Cecil Plains	Hermitage	Freeling	Tamworth AI	Croppa Creek	Gatton
Name Host	unknown	Gilbert	Shepherd	Shepherd	Shepherd	Shepherd	Shepherd	Shepherd	Compass	Compass	Compass	Compass	Cape
BS89-4-3	**10.0**	**10.0**	**10.0**	**10.0**	**8.5**	**10.0**	**10.0**	**10.0**	**10.0**	**8.5**	**9.5**	**9.0**	5.5
Gilbert	**9.5**	**10.0**	**10.0**	**9.5**	**9.0**	**10.0**	**10.0**	**9.5**	**9.0**	**6.5**	**9.0**	4.5	3.5
Westminster[b]	**8.5**	**8.5**	**6.5**	**7.5**	5.0	**8.0**	**8.5**	**7.0**	4.0	2.5	3.0	2.0	2.0
Shepherd[b]	3.5	**10.0**	**9.5**	**10.0**	**9.0**	**10.0**	**10.0**	**9.5**	2.5	1.0	2.5	1.0	3.0
CIho 11458	3.3	**7.5**	**7.5**	**8.5**	3.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Oxford	**8.0**	5.0	5.5	**7.0**	3.5	1.0	1.0	1.0	3.0	1.0	4.0	3.5	2.0
Skiff	**9.2**	3.0	3.5	3.5	2.5	1.0	1.0	1.0	1.5	1.0	1.0	1.5	1.0
Compass[b]	**7.5**	3.5	4.0	2.5	2.0	3.0	3.5	3.0	**9.5**	**9.0**	**9.0**	**9.0**	**8.5**
Navigator[b]	5.6	4.5	6.0	5.5	3.5	5.5	5.5	5.5	**7.5**	**9.5**	**9.0**	**9.5**	**10.0**
Prior	2.4	1.0	1.5	1.0	1.5	2.0	1.5	2.5	1.5	1.5	1.5	2.5	**10.0**
Fleet Aust.[b]	4.9	4.5	5.0	4.5	3.5	4.0	3.5	3.0	1.0	1.5	1.0	1.0	1.0
Rosalind[b]	4.5	1.0	1.0	1.0	1.0	1.0	1.5	1.0	3.0	2.0	2.5	3.0	2.0
Scope CL[b]	3.9	3.0	2.0	2.5	1.5	3.5	2.5	3.0	3.0	2.5	1.5	1.0	1.0
Maritime[b]	3.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	2.5	2.5	3.0	1.5
PSR#167	3.0	3.5	4.0	missing	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Net form net blotch control

Appropriate stubble management

Infested stubble is a source of inoculum for the following season. Avoid planting barley into barley stubble particularly if the crop that produced that stubble had conspicuous NFNB. It is best to follow a non-host crop like wheat, canola, chickpea etc. If you must plant barley on barley then removing the stubble by baling, incorporation by cultivation or even burning will reduce inoculum levels.

Resistant varieties

Sowing varieties with a resistance rating of MS or better is the most economical and convenient form of disease control. Resistance ratings are available on the NVT website or alternatively contact your agronomist or regional pathologist for further information.

Seed and in furrow treatment

During favourable conditions at flowering, the seed can become infected with NFNB. Seedlings from diseased seed can become infected with NFNB before they emerge. If planting seed was sourced from a crop that had significant NFNB then it should be treated with a systemic seed dressing containing active ingredients such as carboxin + thiram and difenoconazole to disinfect seed. Fluxapyroxad is reported to give systemic protection up to middle of heading (GS55). In furrow treatment of fertiliser with azxoxystrobin + metalaxyl-M is claimed to supress NFNB infection for up to 90 days.

Fungicides

Control with foliar fungicides should aim to protect the top two leaves and flag leaf sheath. Good results can be achieved with a single spray when a registered product is applied at around GS49 and before the target leaves become infected. Even better control can be achieved with a two spray strategy, one at GS31 and another at GS49. It is generally not economically worthwhile to apply fungicides to varieties with NFNB disease ratings of MS or better.

Crop monitoring

Fungicides are more effective if applied before NFNB becomes established. This demands regular crop monitoring from about mid tillering. In seasons that are particularly favourable for disease development more frequent monitoring may be necessary.

Conclusion

Net form net blotch is likely to continue to increase on Commander® and Shepherd®, necessitating an integrated approach to disease management for these varieties. Both varieties should still be able to be grown successfully with appropriate crop rotation, application of seed dressings, close monitoring of crops and timely fungicide application.

We are currently pathotyping samples collected in 2016 and a more comprehensive picture of the NFNB population in the Northern Region will be available by June.

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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 authors would like to thank them for their continued support.

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Loose smut in 2016

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Key words

Loose smut, seed treatment, fungicides, seed-borne

GRDC code

DAQ00187

Take home message

- Annual seed treatment with an effective fungicide is the best means to control loose smut.
- Loose smut infects heads at flowering and survives inside the seed.
- Some varieties are more susceptible to loose smut than others.
- Fungicides differ in their efficacy against loose smut and 100% control is difficult to achieve.
- Resistance to loose smut is not considered a high priority of barley breeding programs in Australia and control relies on the use of effective seed treatments.
- Effective seed treatment depends on choice of product, thorough application of fungicide and treatment of planting seed annually or not less than biannually.

Background

Loose smut (*Ustilago nuda*) was detected in a number of barley crops in the northern region in 2016.

Low levels of infection were reported in several varieties with crops of the Hindmarsh(Þ) lineage e.g. Hindmarsh(Þ), La Trobe(Þ) and Rosalind(Þ), often infected.

Loose smut is most conspicuous at around flowering when infected heads bearing a mass of dark brown to black sooty spores are visible among the green heads of unaffected plants. This stark contrast in colour can lead to exaggerated estimates of infected heads. Losses in yield equate to the percentage of infected heads and the detection of greater than 0.1g of loose smut particles in a half litre harvest sample will result in rejection of grain deliveries.

Several fungicides are registered for the control of loose smut; but the levels of control vary among products.

Smuts of barley

In Australia, barley is host to two species of smut – loose smut and covered smut (*Ustilago hordei*) - where infection results in florets producing thousands of spores in individual florets instead of grain. In both species the resultant spore masses are encased in a membrane. This membrane is quite fragile in loose smut but much more persistent in covered smut.

In plants infected with loose smut, the membrane ruptures soon after heading, releasing spores which are carried on the wind to infect surrounding florets. Infection occurs under moist conditions at temperatures around 16 – 22°C. Florets are susceptible to infection from flowering to about one week after pollination.

Germinating spores infect the ovary and the fungus then survives as mycelium within the embryo of the infected seed. It can persist for extended periods in this state. Once infected seed is sown, it

germinates and carries the fungus in the growing point of the plant until it manifests as the symptomatic black spore masses at head emergence. Loose smut is well adapted for survival in that infected plants are usually slightly earlier than healthy plants, ensuring an adequate supply of inoculum when the bulk of the crop is flowering.

Loose smut is exclusively internally seed-borne while covered smut is either externally seed-borne or survives in the soil. The life cycle of loose smut in barley is the same as in wheat; however barley loose smut will not infect wheat and vice versa. See Figure 1.

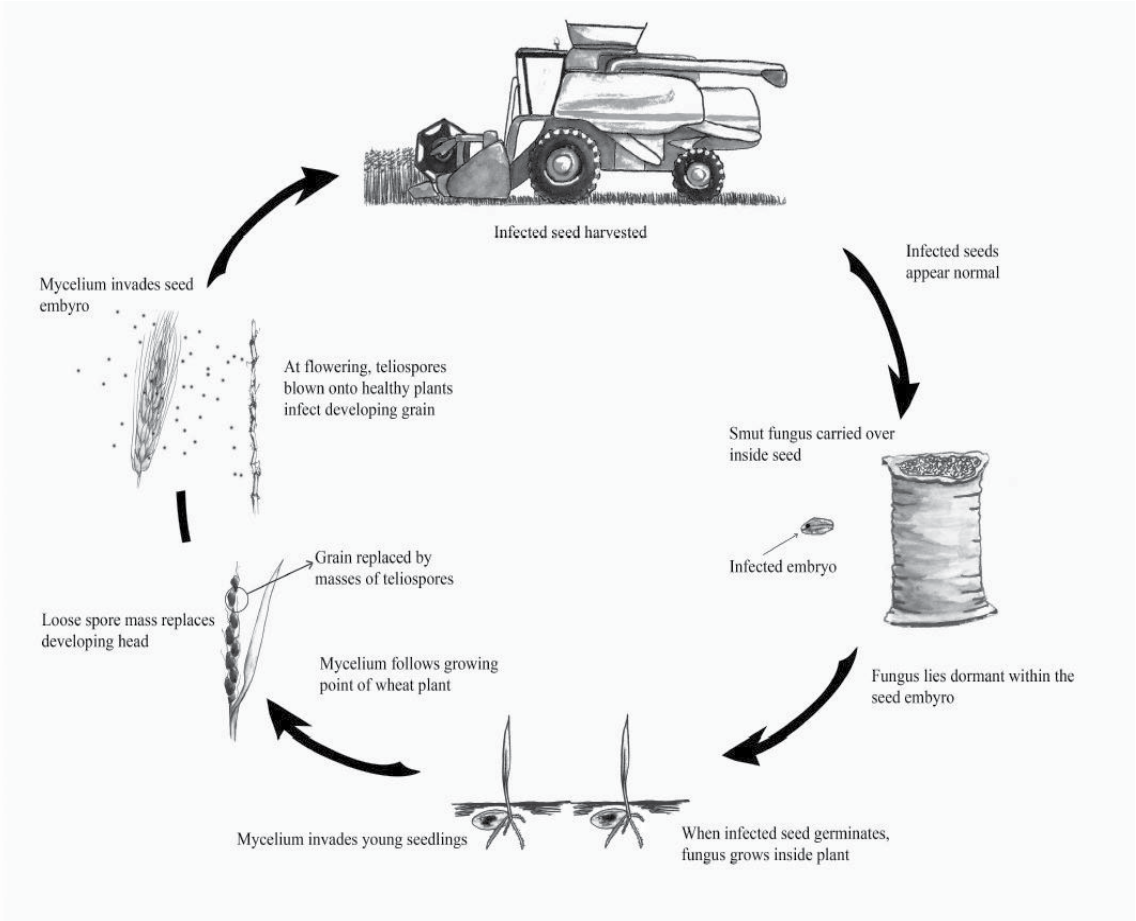

Figure 1. Life cycle of loose smut of barley (and wheat). (Image Courtesy of CropPro).

Control

The level of loose smut in a crop is a function of

- Varietal susceptibility
- The number of grains infected in the previous seed crop
- The efficacy and rate of the seed treatment applied and
- The precision of the seed treatment process

Resistance to loose smut is available; but has never been viewed as a priority objective of Australian barley breeding programs. Seed treatment has provided economical control of the disease for the past 50 years and is likely to continue to do so. As the loose smut fungus is internally seed-borne, systemic fungicides are necessary for control. Products containing carboxin, difenoconazole, flutriafol, fluxapyroxad, ipconazole, penflufen, tebuconazole and triticonazole are registered for the control of loose smut; but their efficacies against the disease vary.

A selection of smuticides was evaluated by the Department of Agriculture Western Australia and Bayer Australia in 2013 and demonstrated superior control by EverGol®Prime (penflufen), Jockey® Stayer® (fluquinconazole) + Raxil®T (tebuconazole) and Vibrance® (difenoconazole+metalaxyl+sedaxane). Their results are summarised in Table 1.

The precision of seed treatment can also impact on fungicide performance. Application machinery must be well calibrated, fungicide suspensions continuously agitated and seed mixed thoroughly to ensure even distribution of chemical on the seed.

Table 1. Loose smut control from a range of fungicides

Product name	L/tonne seed	Active ingredient	$ at 50kg/Ha	% control (DAFWA)		% control (Bayer)	
				Gibson	Wongan Hills	Regans Ford	Wubin
EverGol®Prime	0.4	penflufen	2.86	100a	100a	100a	97a
Vibrance®	1.8	difenoconazole + matalaxyl + sedaxane	2.67	NA	NA	97a	86a
Jockey® Stayer® + Raxil® T	3 + 1	fluquinconazole + tebuconazole	7.68	99a	99a		
Raxil T	1	tebuconazole	0.93	93a	77b		
Vitaflo® C	2.5	carboxin	3	93b	99a		
Zorro® (discontinued)	4	imidacloprid + triadimenol	4.95	87c	85b		
Rancona® C	1	ipconazole	1.55	85c	78b		
Jockey Stayer	3	fluquinconazole	6.75	76d	61c		
Baytan® T	1	triadimenol	2.18	NA		75b	64b

Source: Hills (2015) Controlling loose smut in 2016.

Conclusion

The reappearance of loose smut in barley in 2016 is a reminder to maintain effective fungicide treatment of planting seed. If seed is sourced from a crop known to have been infected with loose smut, it would be wise to treat seed at the higher recommended rate. The increased incidence of loose smut may be due to good infection conditions during flowering in the parent seed crop; it may be due to application of lower rates of fungicide or it may simply be that new varieties are more

susceptible. Whatever the cause, vigilance in routine, quality seed treatment should continue to provide effective control of the disease into the future.

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Scald and other wet season diseases - what did we learn in 2016?

Greg Platz, Lisle Snyman & Ryan Fowler, Dept of Agriculture and Fisheries

Key words

Scald, head blight, environment, crop monitoring, disease control

GRDC code

DAQ00187 – National Barley Foliar Pathogens Variety Improvement Program (NBFPVIP)

Take home messages

- Disease epidemics are a function of presence of a virulent pathogen, availability of a susceptible host and environmental conditions favourable to the pathogen.
- Environmental conditions that are optimal for a particular pathogen signal potential for that pathogen to develop into an epidemic.
- Foliar diseases have a propensity for rapid increase where there are widespread sowings of susceptible varieties and environmental conditions are favourable for pathogen infection, sporulation and dissemination.
- Mild, wet seasons should trigger more frequent crop monitoring to detect unexpected increases in disease.
- Good disease control can usually be achieved by application of an appropriate fungicide before diseases become well established.

Background

Scald (*Rhynchosporium commune*) and other wet weather diseases like Fusarium head blight (*Fusarium* spp.) and white grain (*Eutariosporella* spp.) are considered minor diseases of the traditional GRDC northern region (north of Dubbo). Minor because the annual economic impacts of these diseases when averaged over time, is relatively minor. However in seasons when environmental and epidemic conditions are particularly favourable for these diseases, their economic impact can be quite serious.

Scald has been detected at levels that reduce yield as far north as Toowoomba but this is a rare occurrence. It was present at damaging levels in several crops in the Tamworth area in 2003 and at interest levels in 2005 and 2006. It is essentially a disease of barley in southern and Western Australia where ambient temperatures and frequent rainfall events favour the disease.

Both head blights were recorded but in Queensland were mostly confined to the western Downs. They did not reach epidemic proportions in 2016.

As scald was the most conspicuous of the minor diseases to pose a problem in 2016, this paper will focus on that disease to demonstrate the principles of why a minor disease can become a major disease in some areas and seasons and what can be done to prevent such diseases becoming a similar problem in future seasons.

Why did scald become a problem in 2016?

Three factors are essential for any crop disease to occur:

1. A susceptible host
2. A virulent pathogen and

3. A favourable environment.

In plant pathology this trinity is often referred to as the disease triangle which encapsulates the basics of disease epidemiology. If we dissect the scald "epidemic" in 2016 in terms of the disease triangle, it will provide a better understanding of why it reappeared as a problem last season and forewarn us of the potential for it and other diseases to create epidemics in future seasons.

Susceptible host

Most varieties of barley developed for the northern region are susceptible (S) to very susceptible (VS) to scald, because resistance to the disease in this region is not seen as a breeding priority. This not only provides a susceptible host in areas where scald might over-season and infect any one variety; but it also provides large areas of other susceptible varieties, making an easy target for spores to be deposited and infect. Therefore a high proportion of spores released by the pathogen will find a target host, infect and establish the disease in new areas.

Virulent pathogen

Scald is a highly variable fungus and many pathotypes have been identified. It is claimed that numerous pathotypes can be isolated from just one square metre of infected crop. Consequently, virulent pathotypes are omnipresent.

The pathogen survives on barley stubble, on barley grass (*Hordeum leporinum, H. glaucum*) and can be seed-borne. Barley stubble is most likely the major source of inoculum in 2016. The disease has probably been present in crops at low levels in most seasons and has persisted over summers on crop residues. Winter environments in recent years have not suited the development and spread of scald in crop; so it has persisted at only low levels. It is unlikely that seed-borne infection played a major role in the recent epidemic.

Once infection occurs scald can proliferate at an alarming rate. A single scald lesion can produce up to 1 million conidia (Mathre 1997).

The over-seasoning phases have implications for future disease management. Stubble from crops of barley, heavily infected in 2016, will be a major source of inoculum in 2017. Stubble could be removed but if this is not an option, do not sow barley back into those paddocks for at least 2 seasons. Stubble has been shown to support sporulation over a 10 month period.

Furthermore if growers harvested seed from heavily infected crops in 2016 intending to save some for planting seed in 2017, it is recommended that they either buy in seed from non-infected crops or alternatively treat seed with a recommended fungicide. Transmission of scald from infected seed to seedlings can be as high as 86%.

Favourable environment

The authors believe that this was the key to the 2016 scald epidemic. Scald requires free moisture for sporulation and infection and relies on rain splash to move spores up the plant and within the crop. Frequent rain periods therefore promote sporulation, disseminate conidia and favour infection. These conditions also promote crop growth; so that in dense crops leaf tissue can remain wet for 24 hours per day. Serious losses to scald occur in seasons with frequent rain (Wallwork 2000).

The optimal temperature for spore production is 15 – 20°C which also favours infection. No doubt environmental conditions that promoted spore production, spore dissemination and infection occurred repeatedly in the problem areas in 2016 and played a major role in the development of epidemics.

Control

Unusually wet weather should trigger alarm bells for disease control. If you are in an area that has experienced diseases like scald before, then be suspicious that these diseases may reappear. Monitor crops for the presence of the regular diseases but also with a purpose to detect other diseases that have appeared in previous wet seasons.

Be proactive! Usually minor diseases do not command routine procedures to control the disease. Although once detected in a favourable season, they demand close monitoring and timely fungicide intervention to minimize yield losses. Foliar fungicides are quite effective on scald and will give protection for 3-4 weeks depending on product and rate applied. In a season like 2016, application of fungicide at GS31-32 and again at GS39-41 may have been required to give an adequate level of control.

Conclusion

It has been over a decade since scald occurred at damaging levels in the northern region, north of Dubbo. While the 2016 experience is unlikely to be a frequent occurrence, it is a reminder that given the right conditions, minor diseases can rapidly increase and cause significant yield loss.

The reappearance of scald was a “new” experience for many growers and agronomists. Consequently, it was easy to overlook the disease early in the season and later to underestimate the potential for epidemic increase. By the time scald was recognized as an issue, the optimal time for fungicide application had passed. No doubt the disease reduced yield in heavily infected crops.

So what did we learn in 2016?

Minor diseases can become major diseases when very susceptible varieties are grown under environmental conditions very favourable to the disease. Unseasonal wet weather should signal “look out” warnings. Look out for the common diseases favoured by wet weather but also look out for diseases that are less common and have been a problem in the past. This demands more frequent - and more careful monitoring to detect the diseases less encountered. If in doubt, consult your agronomist or regional pathologist for assistance in the identification of “different” leaf, head or stem symptoms and what options are available should control be warranted. Where application of foliar fungicides is one of those options, spraying too early is much better than spraying too late.

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Nitrogen management in wheat 2016 – method, timing and variety

Richard Daniel, Denielle Kilby and Linda Bailey, Northern Grower Alliance

Key words

Nitrogen, wheat, yield and protein

GRDC code

NGA00004

Take home messages

1. The rate of nitrogen applied was the main factor impacting yield and grain quality in all trials.
2. Urea spread with no physical incorporation, provided equivalent crop responses to urea spread and incorporated.
3. There was no consistent impact from N application timing.

In recent years, NGA have been heavily involved in projects focussed on nitrogen (N) application strategies in wheat, particularly to assist the management of high yielding, and frequently lower protein achieving, wheat varieties such as EGA Gregory(b) and Suntop(b). In 2016 the trial activity focussed on two main areas; 1) the impact of method of application of urea (spread v incorporated) and 2) the impact of timing of urea application (comparing December, February and planting application).

What was done?

Three sites were established in 2016 in paddocks identified by agronomists and growers as low in nitrogen or expected to be N responsive. Suntop(b) was the test variety in three N method x timing trials with EGA Gregory(b) and Lancer(b) evaluated in three variety comparison trials. Both approaches were conducted at each trial site with urea as the only nitrogen source.

All trials were established using small plot planters with row spacings of 32cm and plot lengths of 9-12m. The N application approaches evaluated were;

Suntop(b) timing and method trial

- Application A - N spread and then incorporated by narrow point tynes (fallow Nov/Dec)
- Application B - N spread on soil surface (fallow Nov/Dec)
- Application C - N spread and then incorporated by narrow point tynes (fallow Feb)
- Application D - N spread on soil surface (fallow Feb)
- Application E - N spread immediately before sowing and incorporated by sowing (IBS) with narrow point tynes (sowing)
- Application F - N spread immediately post sowing (PSPE) and
- Application G - N spread in-crop at GS30

EGA Gregory(b) and Lancer(b) variety comparison trial

- Application A - N spread on soil surface (fallow Feb)
- Application B - N spread immediately before sowing and incorporated by sowing (IBS) with narrow point tynes (sowing)

- Application C - N spread in-crop at ~GS30

Table 1. Site and application details 2016

	Macalister	Billa Billa	Tulloona
Previous crop	Wheat	Wheat	Chickpea
Available soil nitrogen sowing (kg N/ha)	100 (0-120cm)	118 (0-120cm)	79 (0-120cm)
Fallow (Nov/Dec)	7/12/15	30/11/15	14/12/15
Timing and quantity of next rain	25mm 5-6 DAA	11mm ~16-17 DAA	17mm 2-3 DAA
Fallow (Feb)	29/2/16	15/2/16	23/2/16
Timing and quantity of next rain	9mm 19-22 DAA	31mm 5 DAA	2mm 25 DAA
Sowing	22/7/16	10/5/16	14/6/16
Timing and quantity of next rain	9mm 12 DAA	14mm 17 DAA	22mm 6 DAA
In-crop	26/9/16	11/7/16	8/8/16
Timing and quantity of next rain	11mm 8 DAA	10mm 30 DAA	6mm 4 DAA
In-crop rainfall (mm)	178	242	280

NB Available soil nitrogen = total soil mineral N kg/ha (to soil depth) using bulk density of closest similar soil type It does NOT include any mineralisation credit. DAA= Days after application. Macalister planting was very delayed due to absence of planting moisture.

Table 2. Suntop® timing and method trial: key treatments evaluated

Application	Description	kg N/ha
A & C	Fallow incorporated	50, 100, 200
B & D	Fallow spread	100
E	Spread and IBS	50, 100, 200
F	Spread PSPE	100
G	In-crop	50, 100

NB the 200 kg N/ha rates were included in an attempt to over-fertilise.

Three split applications of a total of 100 kg N/ha were also evaluated. All had 50% of the N incorporated at either the fallow timings or the IBS application followed by 50% spread at GS30.

Table 3. EGA Gregory® and Lancer® variety comparison trial: key treatments evaluated

Application	Description	kg N/ha
A	Fallow spread	50, 100, 200
B	Spread and IBS	50, 100, 200
C	In-crop	50, 100, 200

NB the 200 kg N/ha rates were included in an attempt to over-fertilise.

Two split applications of a total of 100 kg N/ha were evaluated. Both had 50% of the N applied at either the fallow timing or the IBS application, followed by 50% spread at GS30.

Rainfall for incorporation of spread urea (see Table 1)

Conditions for natural incorporation (rainfall) of urea spread at the December fallow timing were considered good at Macalister and Tulloona (both >15mm within 2-6 days of application) but poorer at Billa Billa (~ 2 weeks until first rainfall). Following the February fallow timing, conditions were poor (~ 3-4 weeks until first rainfall) at both Macalister and Tulloona. Macalister and Billa Billa did not receive their first rainfall after sowing was until ~ 2-3 weeks. The Billa Billa site did not receive any rainfall after the GS30 application for 30 days.

Results

1. Were the sites actually nitrogen responsive?

When dealing with nitrogen response trials, the most basic consideration is whether the sites were actually N responsive. NDVI (Normalised Difference Vegetation Index) was used to provide an objective in-crop assessment of nitrogen response. A larger NDVI ratio indicates increased biomass and/or greener treatments. Figure 1 shows the Suntop® NDVI results, at each site, from the factorial analysis of urea applied at three rates and three timings.

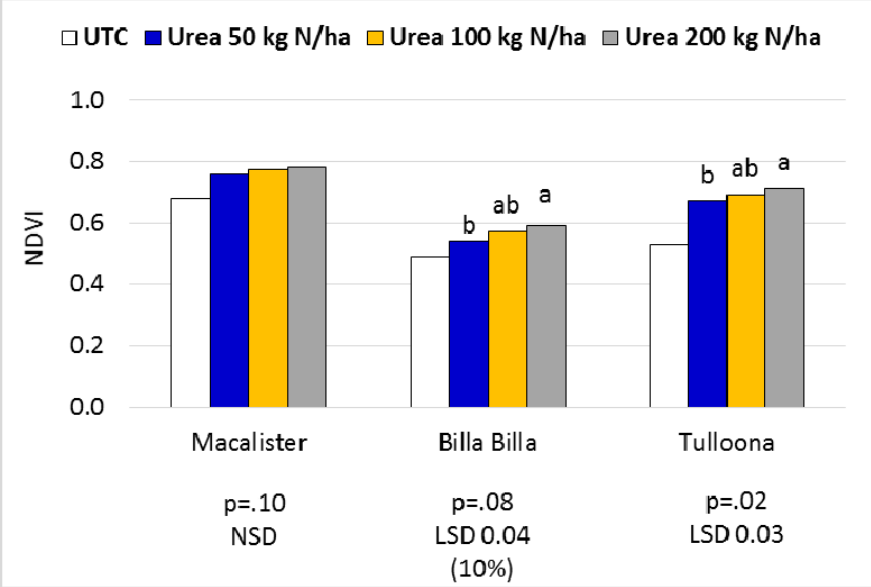

Figure 1. Suntop® NDVI responses to nitrogen rate by trial site when assessed in mid-September to mid-October

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05, except Billa Billa where p=.10.

- Although there was no significant N rate response at Macalister, all N treatments applied in the fallow or at planting provided a significant increase in NDVI compared to the UTC.
- **NDVI results indicated all sites were responsive to added nitrogen.**

Figure 2 shows the Suntop® factorial analysis of yield when urea was applied and incorporated at three rates and timings.

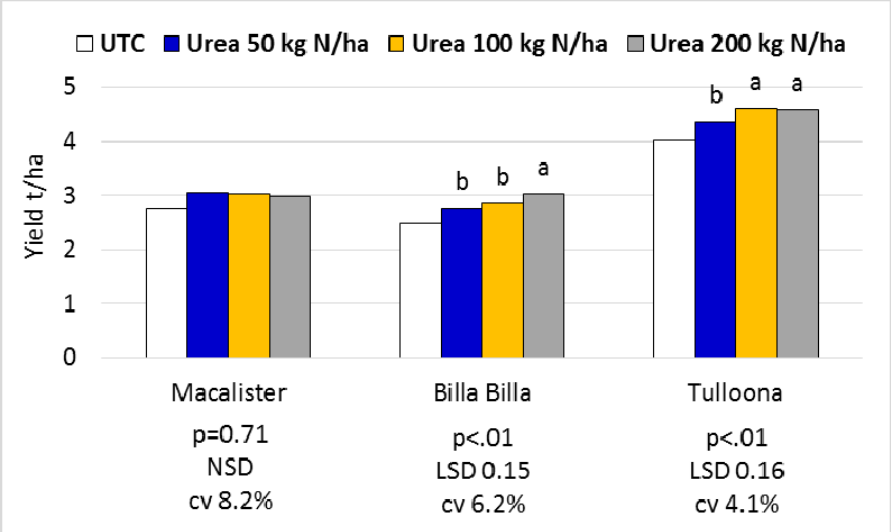

Figure 2. Suntop$^{\phi}$ yield responses to nitrogen rate by trial site. All treatments applied and incorporated at three timings.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05.

- The 200 kg N/ha rate resulted in a significant yield increase compared to the 50 kg N/ha rate at both Billa Billa and Tulloona.
- The Macalister site was less responsive to applied nitrogen than Tulloona or Billa Billa

Figure 3 shows the Suntop$^{\phi}$ factorial analysis of protein when urea was applied and incorporated at three rates and timings.

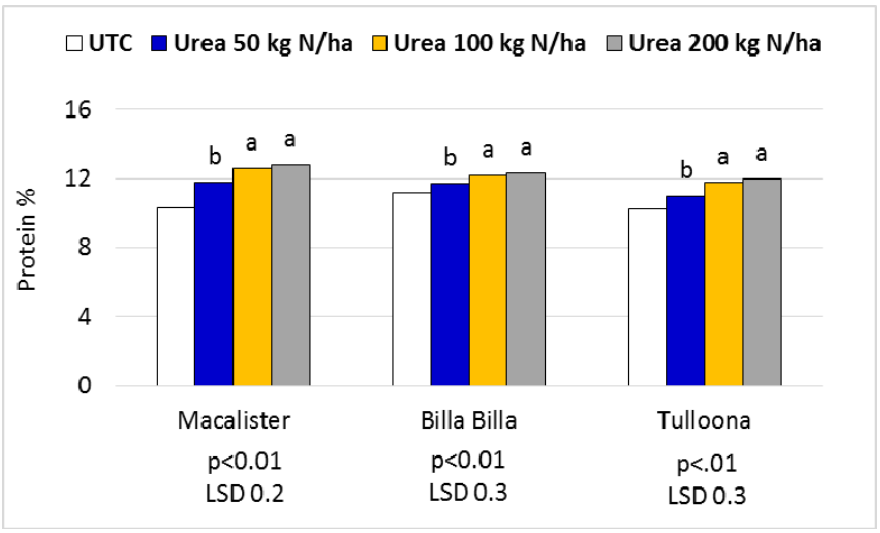

Figure 3. Suntop$^{\phi}$ protein responses to nitrogen rate by trial site. All treatments applied and incorporated at three timings.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05.

- Both the 100 and 200 kg N/ha rates resulted in a significant increase in grain protein compared to the 50 kg N/ha rate - at all sites, in both sets of trials.
- Protein level appeared to plateau at 100 kg N/ha in these trials.
- **Grain protein levels at all trial sites were highly responsive to nitrogen.**

Overall: All sites were nitrogen responsive with grain protein the most responsive followed by NDVI and yield. This was similar to results from 2014 and 2015 trial activity.

2. What were the key comparisons of interest?

Two of the key areas of focus in these trials were:

a) Method of application

b) Timing of application

a) Method of application

The Suntop® trial was designed to assess the method of application of urea. A rate of 100 kg N/ha was applied in December, February and at planting. At each timing, treatments were spread and incorporated on the same day with narrow point tynes or spread with no physically incorporation. In addition a split application treatment was included with 50 kg N/ha incorporated at each of the timings and then followed with 50 kg N/ha spread in-crop at GS30.

Figures 4 and 5 show the Suntop® factorial analysis of yield and protein when urea was applied at 100 kg N/ha using the three different methods of application.

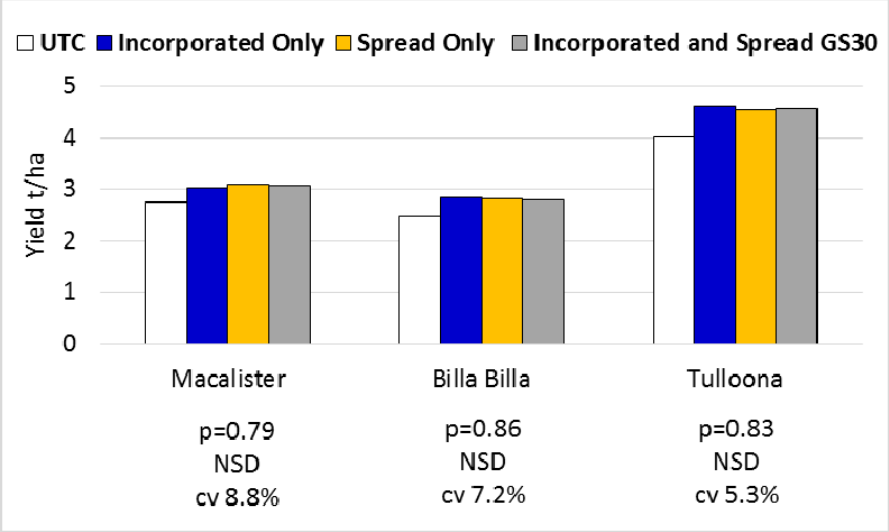

Figure 4. Suntop® yield responses to 100kg N/ha by Method of Application. All treatments were applied at three timings (December, February and planting).

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05

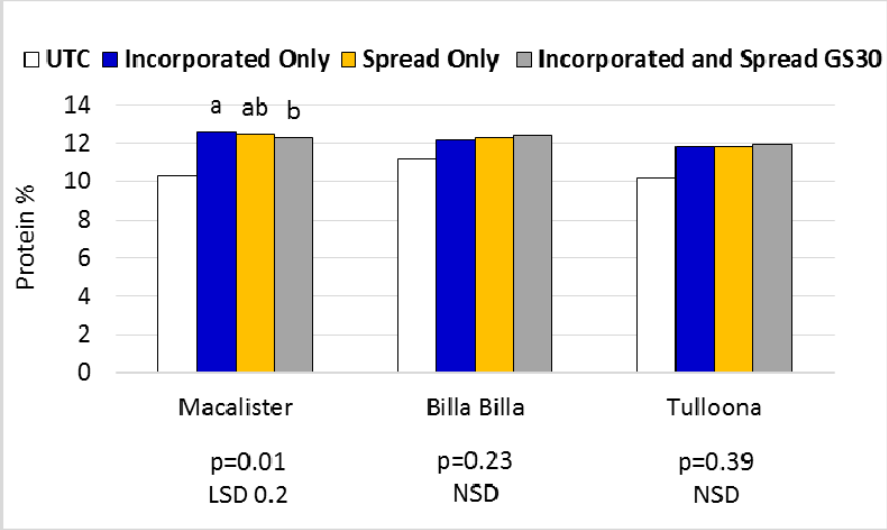

Figure 5. Suntop® protein responses to 100kg N/ha by Method of Application. All treatments were applied at three timings (December, February and planting).

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05

- There was no significant difference in Suntop® yield or protein at any site between 100 kg N/ha applied and incorporated or spread only.
- The split application of nitrogen at Macalister resulted in significantly lower (-0.3%) protein levels than the same total rate of nitrogen incorporated at planting or during the fallow.

b) Timing of application

Figures 6 and 7 show the Suntop® factorial analysis of yield and protein when urea was applied and incorporated at 50, 100 or 200 kg N/ha at all three timings.

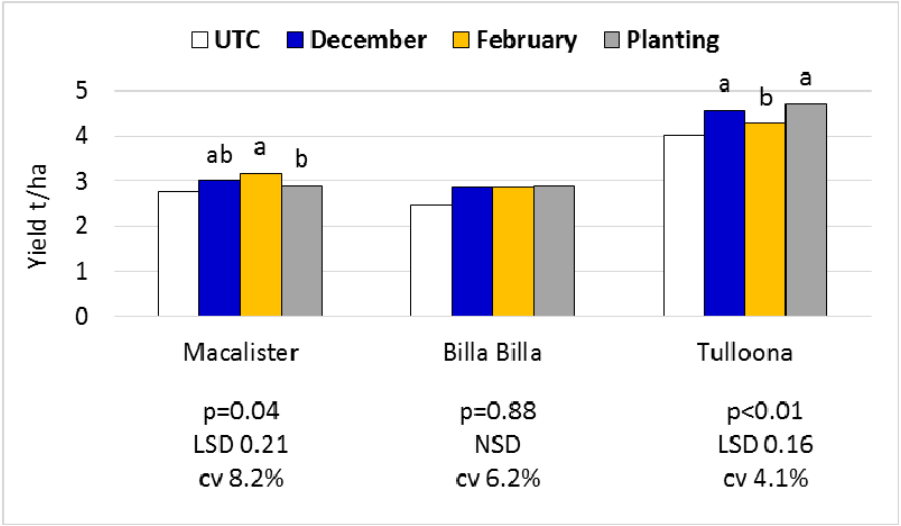

Figure 6. Suntop® yield responses to Timing of Application. All treatments incorporated and applied at three rates.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05

Urea treatments applied at planting in the Macalister trial resulted in significantly lower yield than the same treatments applied in February. This was a site with a high cereal stubble load from 2015 which resulted in some planting difficulties. Crop establishment in treatments where an

incorporation event occurred during the fallow were significantly higher (13-19%) than from planting treatments, in a late sown situation.

Urea applied and incorporated in February in the Tulloona trial resulted in significantly lower yield than the same treatments applied in December or at planting. However, where urea was spread without any incorporation in February, yields were equivalent to the same rate of urea applied at planting (see Figure 8).

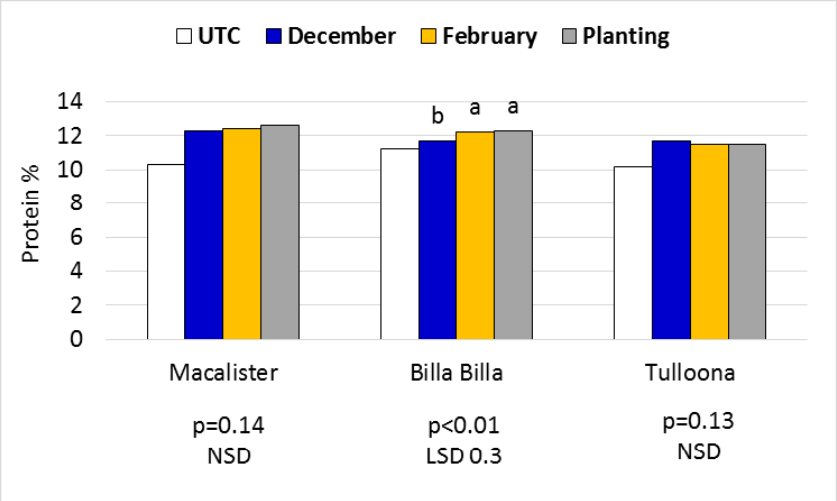

Figure 7. Suntop® protein responses to timing of application. All treatments incorporated and applied at three rates.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05

Figures 8 and 9 show the EGA Gregory® and Lancer® factorial analysis of yield and protein when urea was applied at 50, 100 or 200 kg N/ha at all three timings.

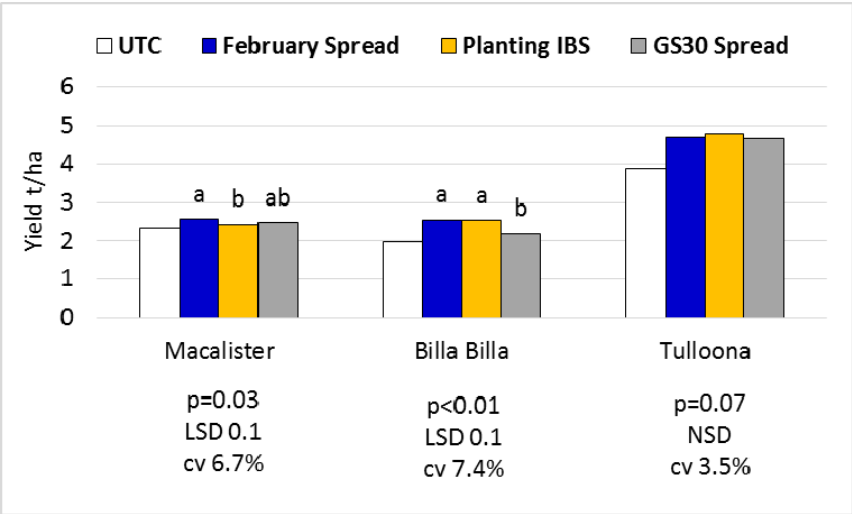

Figure 8. EGA Gregory® and Lancer® yield responses to timing of application. NB February and GS30 treatments spread only.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05

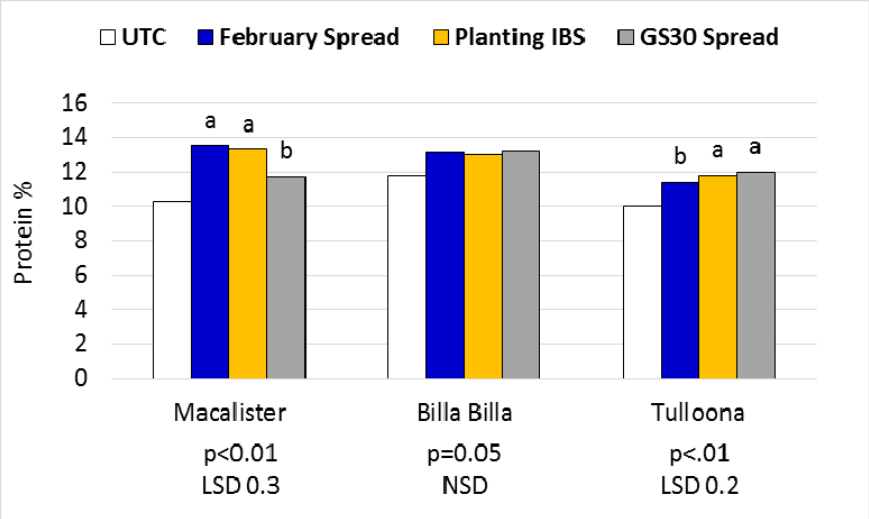

Figure 9. EGA Gregory$^{\Phi}$ and Lancer$^{\Phi}$ protein responses to timing of application. NB February and GS30 treatments spread only.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but graphed for reference. Treatments that share the same letter within each site are not significantly different at P=0.05

- Similar patterns of impact from timing of application were seen in both sets of trials at all sites
- The GS30 only application of urea at Billa Billa was significantly lower in yield than February or planting application. This site did not receive any rain for 30 days after the in-crop application.
- The impacts from timing of application of urea appeared minor compared to the rate of nitrogen applied. Similar results were seen in 2015 comparing February/March timing to a planting application.

Grain quality

Table 4. Suntop grain quality when all urea was incorporated and applied at three timings

Macalister			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	10.3	7.2	GP
50 kg N/ha	11.8 b	9.9 b	AUH2
100 kg N/ha	12.6 a	10.9 a	HPS1
200 kg N/ha	12.8 a	10.8 a	HPS1
	p<0.01, LSD 0.2	P=0.02, LSD 0.7	
Billa Billa			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	11.2	3.3	APW
50 kg N/ha	11.7 b	3.0	H2
100 kg N/ha	12.2 a	3.0	H2
200 kg N/ha	12.3 a	3.0	H2
	p<0.01, LSD 0.3	P=0.98, NSD	
Tulloona			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	10.2	5.2	GP
50 kg N/ha	11.0 b	5.5	GP
100 kg N/ha	11.8 a	5.2	AUH2
200 kg N/ha	12.0 a	5.3	AUH2
	p<0.01, LSD 0.3	P=0.72, NSD	

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but added for reference.
Treatments that share the same letter within each site are not significantly different at P=0.05.

Tables 5-7 show the grain quality results when EGA Gregory(Þ) and Lancer(Þ) were compared with all applications at three timings.

Table 5. EGA Gregory(Þ) and Lancer(Þ) grain quality at Macalister

Macalister- EGA Gregory(Þ)			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	9.8	5.4	GP
50 kg N/ha	11.5 d	7.4 bc	AUH2
100 kg N/ha	12.6 c	9.8 a	AUH2
200 kg N/ha	12.6 c	8.5 b	AUH2
Macalister- Lancer(Þ)			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	10.8	3.0	APW
50 kg N/ha	12.5 c	3.6 e	H2
100 kg N/ha	13.5 b	5.2 d	AUH2
200 kg N/ha	14.3 a	6.4 cd	AUH2
	P=0.02, LSD 0.4	P=0.06, LSD 1.2 (10% level)	

Treatments incorporated at planting but spread only at February and in-crop.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but added for reference. Treatments that share the same letter are not significantly different at P=0.05.

Table 6. EGA Gregory(Þ) and Lancer(Þ) grain quality at Billa Billa

Billa Billa- EGA Gregory(Þ)			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	11.2	4.4	APW
50 kg N/ha	12.0 c	4.2 a	H2
100 kg N/ha	12.4 b	4.0 a	H2
200 kg N/ha	12.7 a	4.0 a	H2
	p<0.01, LSD 0.2		
Billa Billa- Lancer(Þ)			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	12.4	3.0	H2
50 kg N/ha	13.4 c	2.4 c	APH2
100 kg N/ha	13.8 b	2.8 b	APH2
200 kg N/ha	14.2 a	3.2 b	APH1
	p<0.01, LSD 0.2	P=0.01, LSD 0.4	

Treatments incorporated at planting but spread only at February and in-crop.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but added for reference. Treatments that share the same letter for protein are not significantly different at P=0.05, within each variety. Treatments that share the same letter for screenings are not significantly different at P=0.05, across varieties.

Table 7. EGA Gregory and Lancer grain quality at Tulloona

Tulloona- EGA Gregory			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	9.3	5.5	GP
50 kg N/ha	10.3 c	4.7	ASW
100 kg N/ha	11.2 b	4.5	APW
200 kg N/ha	12.1 a	4.0	H2
	p<0.01, LSD 0.2		
Tulloona- Lancer			
N Rate	**Protein %**	**Screening %**	**Receival grade**
UTC	10.7	5.4	GP
50 kg N/ha	11.3 c	4.7	APW
100 kg N/ha	12.4 b	4.7	H2
200 kg N/ha	13.1 a	4.4	APH2
	p<0.01, LSD 0.2	P=0.11, NSD	

Treatments incorporated at planting but spread only at February and in-crop.

UTC= untreated (no additional nitrogen applied). UTC not able to be included in factorial analysis but added for reference. Treatments that share the same letter for protein are not significantly different at P=0.05, within each variety.

- Lancer had significantly higher protein levels (plus ~1%) than EGA Gregory at all sites, despite also having significantly higher yields at two of the three sites
- Lancer had significantly lower screening levels than EGA Gregory at Macalister and Billa Billa.

Grain nitrogen recovery (data not presented)

Grain nitrogen recovery (yield t/ha x protein % x 1.75) was calculated to assess the efficiency of the applied urea. In addition, soil sampling at planting and harvest enabled a grain nitrogen recovery calculation for the UTC. This figure assessed the 'efficiency' of recovery of the available soil NO_3 and NH_4, as determined by soil tests to 120cm depth. Grain nitrogen recovery in the UTC was calculated by dividing the amount of grain nitrogen removed by the amount of soil N depleted eg at Macalister, 50 kg N/ha was removed in the grain from a depletion of 87 kg N/ha in soil N level (soil tests at planting indicated 100 kg N/ha with only 13 kg N/ha remaining at harvest).

In the Suntop trials:

- With all urea incorporated, the grain nitrogen recoveries averaged 23%, 18% and 10% from the 50, 100 and 200 kg N/ha application rates respectively. This is similar to results from 2014 and 2015.
- The grain nitrogen recoveries from soil derived N ranged from 57% at Macalister to 101% at Billa Billa and 128% at Tulloona (for values >100%, it is assumed that additional mineralisation occurred during the cropping period). This is similar to results from 2014 and 2015.

In the EGA Gregory(Þ) and Lancer(Þ) trials:

- Lancer(Þ) had significantly higher grain nitrogen recoveries than EGA Gregory(Þ) at all sites (range from 4-12 kg N/ha)

Economics

Net benefits were calculated using grain receival prices for delivery Moree in mid November 2016. There was a large spread of >$60/t between APH and APW classifications. Figure 10 shows the net benefit/loss across all sites for the Suntop(Þ) trials where all urea was incorporated.

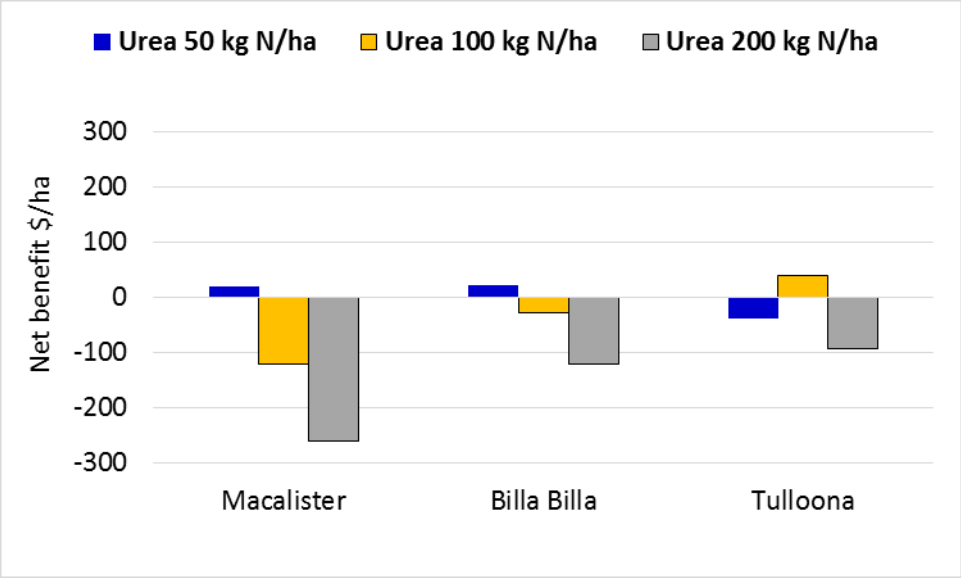

Figure 10. Suntop(Þ) net benefit from applied nitrogen rate by trial site. All treatments applied and incorporated at three timings.

Assumptions: urea at $1.30/kg N ($600/t), spreading cost at planting $25/ha, fallow incorporation at $40/ha, grain prices delivered Moree mid Nov 2016: APH2 $237/t, H2 $202/t, AUH2 $194/t, APW $177/t, ASW $172/t, AGP $172/t and HPS $171/t

Figures 11 and 12 show the net benefit/loss across all sites for EGA Gregory(Þ) and Lancer(Þ) trials.

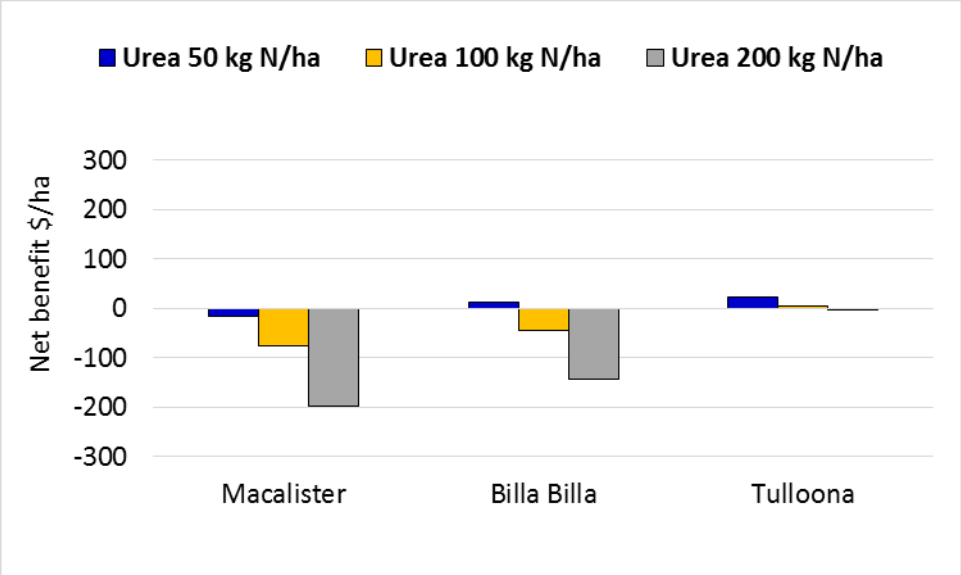

Figure 11. EGA Gregory(Þ) net benefit from applied nitrogen rate by trial site. Treatments incorporated at planting but spread only at February and in-crop.

Assumptions: urea at $1.30/kg N ($600/t), spreading cost $25/ha, grain prices delivered Moree mid Nov 2016: APH2 $237/t, H2 $202/t, AUH2 $194/t, APW $177/t, ASW $172/t, AGP $172/t and HPS $171/t

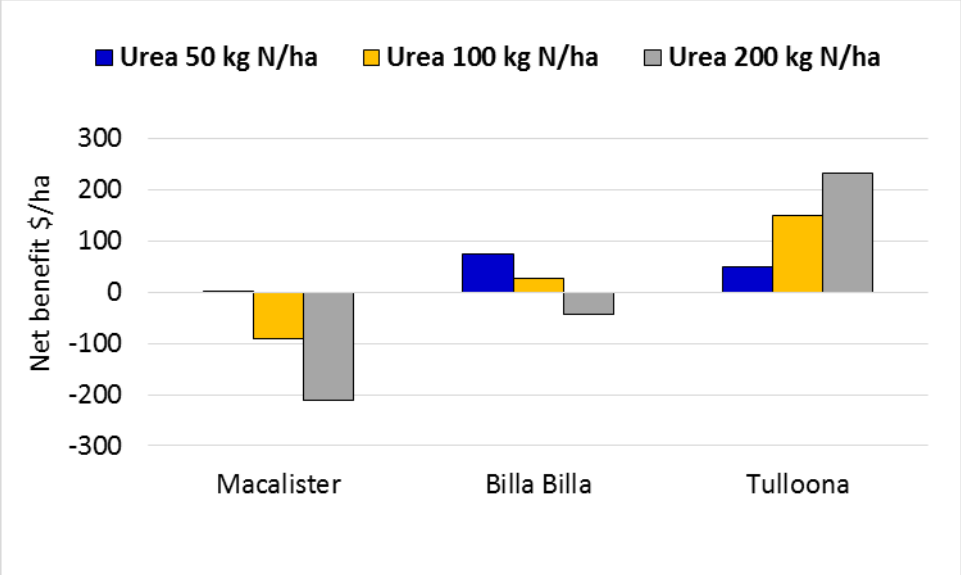

Figure 12. Lancer(b) net benefit from applied nitrogen rate by trial site. Treatments incorporated at planting but spread only at February and in-crop.

Assumptions: urea at $1.30/kg N ($600/t), spreading cost $25/ha, grain prices delivered Moree mid Nov 2016: APH2 $237/t, H2 $202/t, AUH2 $194/t, APW $177/t, ASW $172/t, AGP $172/t and HPS $171/t

- At Macalister and Billa Billa (yields ~2.5-3.0t/ha), the 50 kg N/ha rate was the most economic rate evaluated although net benefits were $20/ha or less for five of the six comparisons.
- At Tulloona (yields >4t/ha), higher rates of N were economic, resulting from both increased yield and improved grain quality.
- Lancer(b) provided the highest net benefits at both Billa Billa and Tulloona, with similar results from all varieties at the Macalister site.

Key points 2016

1. **Nitrogen rate was the key factor impacting yield in both series of trials.**
2. There was no significant impact on yield from method of application.
3. There were significant differences from application timing but these appear to be associated with other agronomy impacts rather than N availability.

Conclusions

The results in 2016 are in line with earlier project activity.

1. The rate of N applied has been the dominant factor affecting yield and grain quality in all twelve trials.
2. The performance of urea spread and not mechanically incorporated has continued to provide equivalent results to urea incorporated at the same timings.

The February fallow application at Tulloona provided the longest interval in the trial series between spreading and first rainfall, with only 2mm at 25 days after application. This data continues to support the N volatilisation results achieved by Dr Graeme Schwenke and indicates that spreading of urea is less risky than previously considered in the northern region. These results are not suggesting there are no N losses. However the losses were small enough that we were unable to measure a difference in the following crop, despite significant N rate responses at each site.

Application of N in the fallow was compared to at planting in 2015 and 2016. The hypothesis tested was that application prior to planting may allow N to distribute more deeply in the profile and provide a 'canopy management' benefit compared to a shallow N concentration at planting. In the eight trials, there has been no consistent difference between application timings in crop yield or grain quality response.

A concern from these trials is that despite all sites recording significant grain protein increases with added N, actual net benefits have only been achieved from EGA Gregory(b) in 4 of the 12 trials.

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 authors would like to thank them for their continued support.

NGA would particularly like to acknowledge the assistance from Jason Schelberg, George Picton and Peter Butler for 2016 trial activity together with Kalyx staff for trial planting, maintenance and harvest. In addition we would like to thank AGT and Pacific Seeds for product supply.

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

Denitrification and managing nitrogen loss risk – key factors affecting loss

Chris Dowling, Back Paddock Company

Key words

N loss, waterlogging, key factors, denitrification risk, managing, avoidance

GRDC code

DAQ00183

Take home message

Denitrification N loss is an unavoidable soil process during crop production in the north. Understanding the key drivers and finding practical N management options in high risk situations or following a significant N loss event is the key to ensuring the economic impact of a denitrification event is minimised.

Background

Denitrification (Dn) risk is ever present in the clay soils of northern Australian grain growing areas. It cannot be eliminated, but by understanding the drivers of the process risk, mitigating N management tactics can be considered. The 5 core driving factors are

- Anaerobic soil conditions (severity and duration)
- Soil nitrate-N (quantity)
- Soil temperature
- Presence of key microbial species
- Availability of a labile carbon source (crop residues)

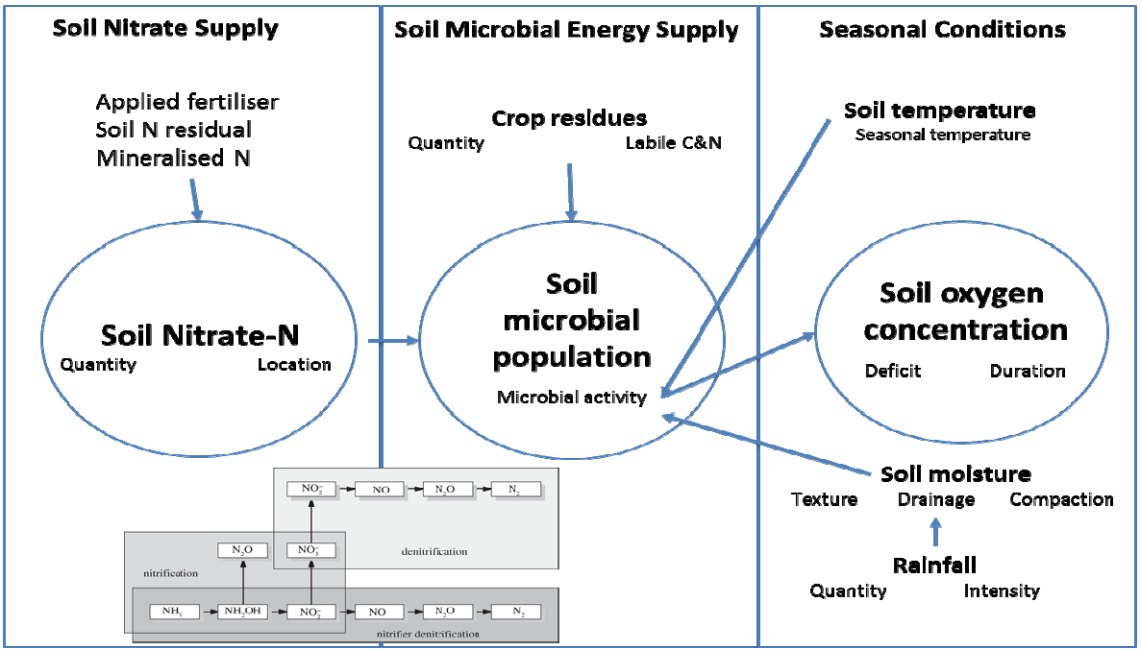

Figure 1. Relationship between key drivers of denitrification

The 5 key drivers are frequently present at levels in clay soils of northern grain growing regions where the main trigger, an anaerobic soil event (most commonly high moisture content), means that

loss is unavoidable. Seasonal losses even in "dry season" can be around 10 % or the total seasonal crop N supply (Pu et al. 2001). Recent research suggests that losses of 20 – 50 % of applied N can occur in a single loss event. For any single Dn event the amount of N loss is related to the starting level of each of core driving factors and the duration of anaerobic soil condition. The total N loss across a cropping year is the accumulated loss of individual Dn events.

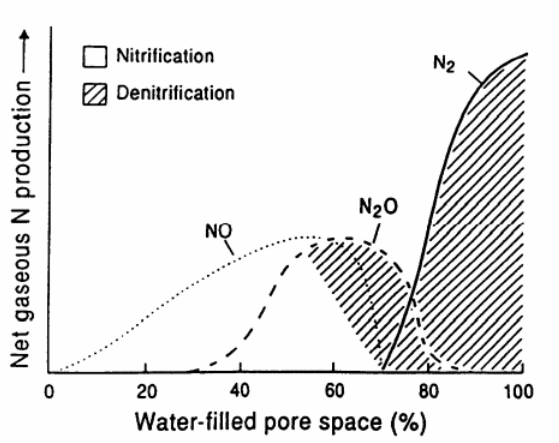

Figure 2. Model of the relationship between water-filled pore space of soil and relative fluxes of N-gases (Yoshinari 1993)

Minimisation of Dn loss is therefore a risk management process, with the key tactic being avoidance the creation of high levels of soil nitrate-N in a situations where risks associated with the other core drivers are high.

Table 1. Rating denitrification risk

Dn Risk factor	Higher Risk	Lower Risk
N source	N source rapidly converts to nitrate-N e.g. rapidly mineralisable fertiliser N	N source converts sequentially with increasing fallow and in-crop moisture accumulation e.g. pulse residues
N Timing	Soil profile > 75 % full leading into high intensity rainfall period Fallow	Soil profile <25 % full In - crop
N Placement	Broadcast into crop residue incorporation layer	Banded below stubble incorporation layer
N Rate	All fertiliser N applied in one application	Split N into lower risk periods Increase N from higher efficiency sources
Drainage	< 1% Dispersive	>5%
Labile carbon	Large amount from previous crop Early fallow	Small amount from previous crop Late fallow
Soil temperature	Summer	Winter

Accurately predicting and modelling the Dn is complex and is still not at a level where simple, reliable decision support tools are currently available. Preventing negative economic effects of Dn events is currently about weighing up the likely loss based on the risk factors (Table 1), assessing

factors such stage of crop season, crop condition, potential cost and returns and taking appropriate action.

Loss during the fallow can also be confirmed by soil testing for soil nitrate-N (0-60 cm) close to planting or early in- crop. Recent experience with soil testing post waterlogging and a rapid large N mineralisation event (e.g. first decent autumn rainfall after a dry summer) suggests that testing should be delayed for 4 – 6 weeks after end of waterlogging event to allow sufficient time for the soil to settle to a new nitrate-N equilibrium (https://extensionhub.com.au/web/crop-nutrition/-/how-to-include-ammonium-n-in-recommendations).

Having a higher proportion of crop N supply provided from mineralisable N sources is a valuable mitigation strategy as are getting nitrate-N deeper in the profile and splitting application timing.

Acknowledgement

The information presented is made possible through the support of the GRDC, the author would like to thank them for their continued support.

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Cereal agronomy – tweaking cereal agronomy to optimise profit from newer varieties

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Notes

Canola agronomy and fit in northern farming systems

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Key words

canola, flowering, phenology, harvest loss

GRDC code

CSP00187

Take home message

- Identifying the optimal flowering window is an important consideration when growing canola in northern environments
- It is important to consider both biotic and abiotic stresses when identifying the optimal window
- Short to mid-season varieties are most suited to northern environments
- A large proportion of the final yield comes from the branches and should be considered when deciding to desiccate or windrow.

Background

This paper has been prepared as part of the GRDC funded project Optimised Canola Profitability (OCP) this is a collaborative project between NSW DPI, CSIRO, SARDI and GRDC. A strong focus of the research to date has been on investigating the interactions between sowing date and variety choice of canola as it relates to phenology, biomass accumulation, grain yield and oil concentration. This focus has arisen from the practice of planting canola earlier in southern Australia as a way of capturing a dual purpose use, improving the crops water use efficiency, increasing yield and adapting to early seasonal breaks. The earlier sowing of canola in the southern states has identified differences in canola genetics, where the time to flowering in some varieties differs from when they are planted within their traditional window. The process of identifying and understanding the different flowering process has helped identify canola cultivars and agronomic practices that can help improve the production of canola in the northern grains region.

Detailed flowering trials that included the extension of day length and monitoring of low temperature sensitivity were established in Queensland and Canberra; while variety by sowing date experiments were planted across the Northern and Southern GRDC regions in 2014,2015, and 2016. These trials extended from the Darling Downs in SE Queensland to Tamworth and the Breeza plain, Narrabri and then on to Canowindra on the central-west slopes of NSW, Horsham in the Wimmera region of Victoria and west to the Eyre Peninsula in South Australia. This paper will use some of these results to highlight issues to consider if including canola within a northern farming system.

Identifying the optimal flowering date

Like chickpeas, canola is an indeterminate plant (will continue to flower while they have water and mild temperatures), unlike chickpeas, however, canola can withstand colder temperatures during flowering, but the flowers and particularly the pods are sensitive to frost. In selecting an optimal flowering window, the aim is to avoid frost during the sensitive pod filling period.

On the other end of the season, high temperatures even for short periods can cause stress resulting in yield loss. Higher temperatures can also reduce the quantity and quality of the oil produced. Temperatures above 25°C can inhibit the build-up of oleic acid and therefore alter the fatty acid composition of the oil.

The detailed phenology work that has been a key part of the (OCP) project has been captured within the APSIM canola model, this combined with field trials conducted across the region has allowed us to identify the best time for flowering to occur. The optimum time to flowering is a period calculated from the model that has been adjusted to consider high temperature and frost stress.

The figure below (Figure 1) describes the optimum flowering window for Moree the grey bar depicts the window when flowering should commence. The predicted yield (black line) decreases from this point because water stress (dotted) and heat (dashed) lines increase the stress on the crop. This data is a summary from 50 years of crops planted on a range of sowing dates using short and medium length canola cultivars.

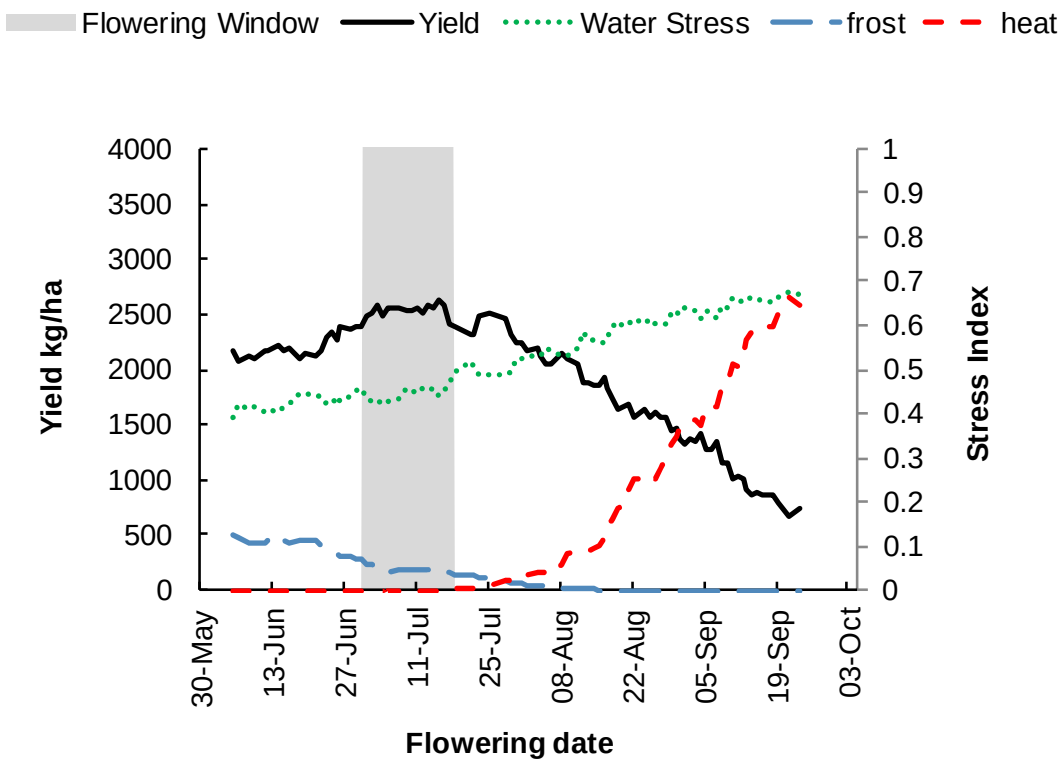

Figure 1. Simulated optimal flowering window for canola production in Moree for short to mid season cultivars. The solid line indicates the frost and heat modified yield. The dotted line indicates increasing water stress and the dashed lines indicate frost and heat stress (frost to August, heat from August).

Once the optimum flowering window has been identified it is important to work backwards and find cultivars that have the correct genetics to flower in this period. For Moree a range of phenology types are presented (Figure 2). The long season types or the winter types are not suited to Moree because they flower too late (not shown). The short season and medium short cultivars are more suitable. Archer is a midum long season and is a possibility for a very early planting, more testing is required.

These results are supported by the trial results collected last year (table1), however, it must be remembered that 2016 was not a typical season with a mild winter and spring allowing good growth well into spring, which resulted in high yields (Table 2).

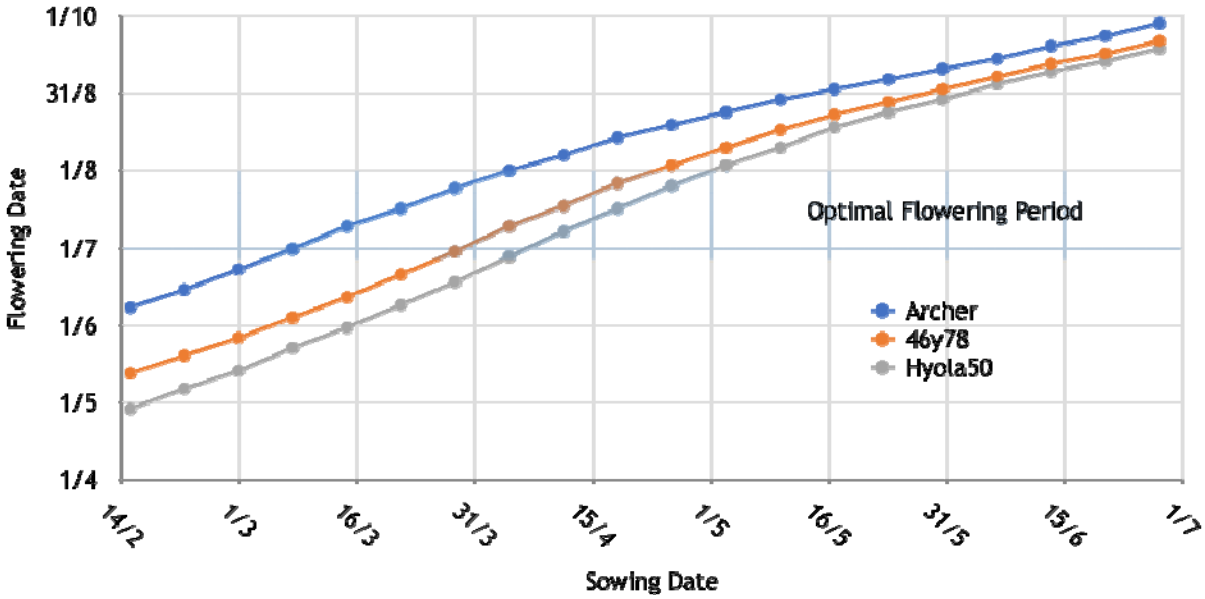

Figure 2. Showing the sowing dates required to flower within the optimal flowering period for different cultivar types.

Table 1. Flowering dates for some current commercial cultivars sown at different times across the northen grains region during 2016

	Norwin			Trangie			Breeza		
Sowing date	**15-Apr**	**29-Apr**	**13-May**	**1-Apr**	**14-Apr**	**17-May**	**13-Apr**	**16-May**	**17-Jun**
Hyola 575CL	14-Jun	29-Jul	29-Jul	7-Jun	10-Jul	19-Aug	16-Jul	26-Aug	12-Sep
44Y89 CL	13-Jun	29-Jul	29-Jul	15-Jun	13-Jul	9-Aug	22-Jul	25-Aug	12-Sep
43C80 CL	13-Jun	29-Jul	29-Jul	25-Jun	19-Jul	*	27-Jul	22-Aug	6-Sep
45Y86 CL	13-Jun	29-Jul	29-Jul	12-Jul	26-Jul	*	25-Jul	22-Aug	16-Sep
45Y88 CL	29-Jul	29-Jul	29-Jul	3-Jul	21-Jul	28-Aug	30-Jul	30-Aug	15-Sep
Archer	29-Jul	29-Jul	15-Aug	29-Jul	5-Aug	31-Aug	11-Aug	5-Sep	22-Sep

Table 2. Yields achieved in time of sowing trials from three sites across the northern grains region.

	Norwin			Trangie			Breeza		
Sowing date	**15-Apr**	**29-Apr**	**13-May**	**1-Apr**	**14-Apr**	**17-May**	**13-Apr**	**16-May**	**17-Jun**
Hyola 575CL	-	3.6	2.6	3.1	3.3	2.6	-	-	-
44Y89 CL	-	4.5	3.2	3.8	3.9	3.0	-	-	-
43C80 CL	-	4.3	3.2	3.5	3.5	*	-	-	-
45Y86 CL	-	3.5	3.5	3.3	3.1	*	3.3	4.0	4.4
45Y88 CL	-	4.5	3.7	3.9	3.1	3.4	-	-	-
Archer	-	2.5	3.8	3.5	3.2	3.2	-	-	-

*43C80 CL and 45Y86 CL had poor establishment from the 17 May sowing date at Trangie so were excluded from the analysis.

Is there a benefit of planting early

Work from the southern grains regions is showing that if rain occurs in ealy April (early sowing) good yields can be achieved by sowing a mid to long season cultivar that flowers in the optimal flowering window. However, this is not the case in warm or northern environments where the warmer conditions prevent longer season cultivars from flowering during the optimum flowering window. Some good, short to medium length cultivars are available for northern environments.

Harvesting

A sucessful canola crop should be planted at a time and with a cultivar that enables flowering to occur within the optimum floweing window. A good profile of stored water and sufficient nitrogen will give the crop the best chance of success. The next important issue is how to harvest that crop. Work conducted by NSW DPI as part of the optimising canola project is idenitifying ways to maintain yield when harvesting canola. The current industry guidelines recomend that canola is ready to windrow when 40-60% of seeds on the primary stem change colour from green to red ,brown or black. However, data from trials conducted in 2015 and 2016 are showing that on average only 25-30 % of the grain is being held on the main stem. This work is showing that later harvesting/windrowing up to 95% colour change on the main stem will increase yield and oil concentration. The tradeoff with delaying is losses through shattering or weather damage, so suggested recommendations are to consider upcoming weather forcasts and windrow when more than 40 % of the mainstem seed has changed colour. If planning to dessicate and direct head, dessicants should be applied after 20% mainstem seed colour change has occured.

Acknowledgements

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Faba bean disease management update

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Keywords

Stemphylium blight, chocolate spot, rust, fungicides

GRDC codes

UA00127, DAN00176

Take home messages

- The high rainfall during the 2016 growing season favoured development of leaf blights in faba bean in the northern grain region.
- By mid-August severe incidences of chocolate spot (*Botrytis fabae*) were found throughout the northern region, particularly in early sown crops. Timely fungicide applications were able to control disease development in most cases.
- High incidences of uncommon leaf blight symptoms were noted at several sites in NSW and Queensland. The disease was identified as Stemphylium blight, caused by generally saprophytic *Stemphylium* spp. Evaluation of disease screening nurseries sown at the NSW DPI Liverpool Plains Field Station (LPFS) showed a wide range in susceptibility in the faba bean germplasm pool, with the recently released variety PBA Warda(b) among the more susceptible genotypes. Currently little information is available on crop losses or management options. However, initial research indicates that the disease would only cause problems in very wet years.
- Trials at LPFS showed substantial yield gains from foliar disease management after fungicide applications, even on the newest, more disease resistant, varieties.
- Only low incidences of rust (*Uromyces viciae-fabae*) were reported in commercial fields of faba bean. This is likely the result of the frequent fungicide applications used to control leaf blights.
- The dry 2015-2016 summer and the wet 2016 winter season reduced aphid populations resulting in the near absence or viruses in northern faba bean crops.
- Following the wet 2016 season, inoculum loads of residue-borne diseases (chocolate spot, Ascochyta blight, rust and – likely – Stemphylium blight) will be high at the start of the 2017 season. Growers are advised to adhere to the recommended disease management strategy for faba bean diseases. Especially important will be the early (6 – 8 leaves) fungicide application. Mancozeb is still the recommended product for the first application, because of its broad spectrum and absence of restrictions on number of applications.

Development of faba bean diseases in the 2016 season

Among the winter pulses, faba bean is the preferred cropping option in the high rainfall zones and for soils that are prone to water logging. However, high rainfall seasons also provide an environment that is favourable for the development of fungal pathogens. Both rust (*Uromyces viciae-fabae*) and chocolate spot (*Botrytis fabae*) have caused significant yield losses over the past years in faba bean in the northern grain region. While rust can be observed in most seasons (even in those with relatively low rainfall), incidences are generally kept below critical levels by the improved resistance in new varieties and by timely fungicide applications. Chocolate spot is typically only of importance during wet seasons, but has then the potential to cause complete crop failure in a few days. Chocolate spot has a very short latent period (1-3 days compared to at least 10 days for rust) and

unlike the obligate rust pathogen, the necrotrophic chocolate spot pathogen grows and sporulates on senescent and dead leaf tissue, thereby massively increasing inoculum loads in the crop. While new faba bean varieties released for the northern region have increased levels of rust resistance, less progress has been made in combining improved chocolate spot resistance with local adaptation.

Proper control of foliar diseases requires timely application of appropriate fungicides when the disease is detected and rainfall events are predicted. Proper diagnosis of the disease is of crucial importance, eg early symptoms of chocolate spot (brown pin-point lesions) can be confused with symptoms caused by spray oils or abiotic stresses or by symptoms caused by other leaf blights.

Fungicide options in faba bean are currently limited. Mancozeb is often the preferred product because of its broad action and the absence of limits on usage frequency. Carbendazim and procymidone are reported to be better options for chocolate spot control, but our fungicide efficacy trials over the past season (results not reported here) showed that both chemistries have no effect on rust development. The same trials showed efficacy of chlorothalonil on both rust and chocolate spot and a superior control of rust by tebuconazole. Use of tebuconazole on faba bean is currently on permit, but restricted to a maximum of three spray treatments per season, at an interval of 14 – 21 days between consecutive sprays. (Permit no: 13752).

Based on our surveys and on samples submitted by growers and agronomists, the important diseases during the 2016 were chocolate spot and (to a lesser extent) Stemphylium blight (see below). Rust was found in very few commercial faba bean crops and did not develop to levels that limited yield. No other leaf blights, like Ascochyta blight or Cercospora leaf spot, were identified. Climatic conditions did not favour aphid development or movement; consequently viruses did not play a role in the 2016 season.

Stemphylium blight

Symptomatology, losses and control options

Unusually high incidences of leaf blight symptoms were observed on faba bean during the 2016 growing season. The symptoms were identified as Stemphylium blight (StB), a disease known to affect lupins and lentils, but rarely reported in faba bean. Several *Stemphylium* species have been reported as the causal agent in lupins and lentils. Species identity of faba bean isolates from different locations in NSW and Queensland is currently being determined by USQ and QDAF using molecular tools.

Early in the season Stemphylium blight was frequently misdiagnosed by growers and advisors as chocolate spot and symptoms can at times be confusing. However, chocolate spot typically starts as small discrete reddish-brown leaf lesions that after extended periods of leaf wetness increase rapidly in size, move to other plant parts and cause severe leaf necrosis, stem collapse and flower and pod abortion. Stemphylium blight is characterised by large grey-black necrotic lesions, often starting from the leaf edge and restricted to leaves and, to a lesser extent, stems. No symptoms were noted on flowers or pods.

Little is currently known about the effect of StB on faba bean yields. However, high incidences on individual plants could be noted in early August, which would have the potential to reduce yields. A preliminary yield loss estimate was made using the varieties PBA Nasma(ℓ) and PBA Warda(ℓ) grown in non-fungicide treated plots at LPFS. On 12 August in each of three plots of each variety, 10 severely (>25 % affected leaf area) blighted branches were labelled as well as a neighbouring unaffected branch. The 120 labelled branches (30 severely affected and 30 non-affected of each variety) were individually harvested and yield parameters measured. Number of pods, number of seeds and seed weight of affected branches was reduced to half of that of non-affected branches (Table 1). These figures are indicative only and likely to represent a 'worst case' scenario, as faba bean can generally compensate early damage by increased branching of neighbouring non-affected plants.

Table 1. Comparison of severely Stemphylium blight affected (s/a) and non-affected (n/a) branches of two varieties grown in non-fungicide treated plots at the Liverpool Plains Field Station, 2016.

	Pods / branch		Seeds / branch		Seed weight (g) / branch	
	n/a	s/a	n/a	s/a	n/a	s/a
PBA Warda(l)	13	7	33	17	21	11
PBA Nasma(l)	10	4	23	10	18	7

No information is as yet available on the efficacy of fungicides for the control of Stemphylium blight on faba beans, lentils or lupins. Our initial results (not reported here) indicate that out of the currently registered fungicides, the application of tebuconazole resulted in lower incidences, but further trials are necessary before reliable recommendations can be made and tebuconazole is not registered for the control of Stemphylium blight in faba beans.

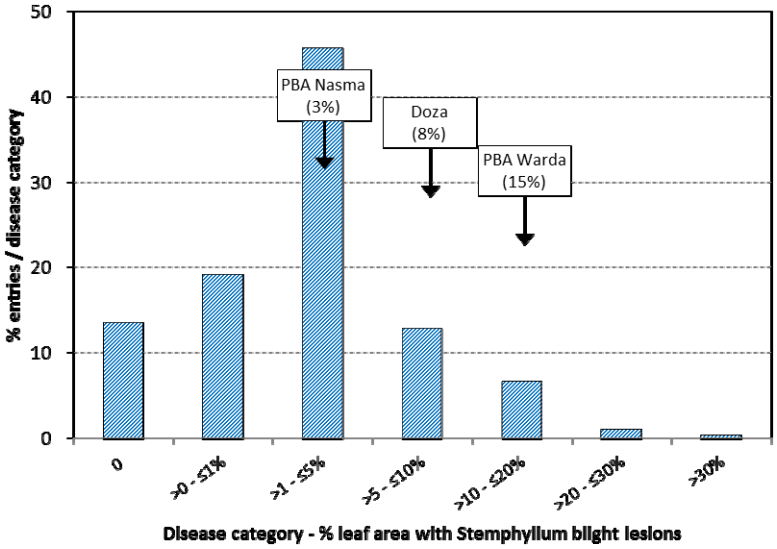

Figure 1. Distribution of 443 faba bean genotypes over Stemphylium blight scoring classes, with %leaf ratings for three current varieries seperately listed, Liverpool Plains Field Station, 10 August 2016

Varietal differences

The evaluation of 443 faba bean genotypes in the disease screening nursery at LPFS showed a non-symmetrical distribution over Stemphylium blight incidence classes, with only 37 entries showing more than 10% blight severity (Fig. 2). The recently (2012) released variety PBA Warda(l) (now the most widely grown variety in the northern region) was among the more affected (15% severity), while PBA Nasma(l) and Doza(l), the other two widely grown varieties in the northern region, had lower levels of infection.

Distribution of the disease within and between plots pointed to a high degree of genetic control. Greenhouse screening tests are ongoing, but initial results confirmed the very large differences in Stemphylium resistance observed in the field among as well as within breeding lines. Clear differences among single plant progenies taken from inbred lines indicate that the resistance is based on a single gene or only a few genes. This is unusual for a saprophytic pathogen, but a similar basis of resistance is operating in the narrow-leaf lupin gene pool against the grey leaf spot disease, which is also caused by a *Stemphylium* spp.

Conclusions

The appearance of Stemphylium blight during the 2016 season is most likely a combination of a very wet season and the growing of a susceptible variety. While the disease will have caused yield losses in severely affected sites, the confusion of Stemphylium blight symptoms with those of other leaf blights (particularly chocolate spot), resulted in unnecessary fungicide applications.

Resistance screening trials are continuing to eliminate from the breeding program highly Stemphylium blight susceptible genotypes. Fungicide efficacy trials are planned for the 2017 season that would allow better recommendations for control as well as providing yield loss data.

Disease tolerance trials

A set of 12 faba bean genotypes, consisting of 6 widely grown varieties (in both the southern and northern region) and 6 advanced breeding lines was tested for tolerance to rust and other diseases at the Liverpool Plains Field Station (LPFS). A split plot design was used with fungicide treatment vs untreated control as the main plots, genotypes as subplots, 3 replicates and a plot size of 15m^2. The trial was located close to the rust inoculated disease screening nursery which provided a heavy rust inoculum load throughout the season.

Fungicide (mancozeb 750 g ai / kg product, applied at 1 kg product / ha) was applied 4 times prior to predicted significant rain events (Figure 1).

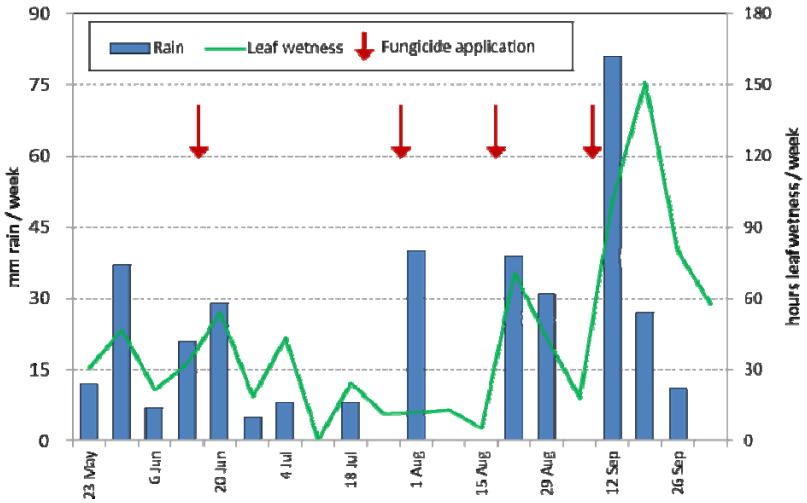

Figure 2. Liverpool Plains Field Station, 2016. Weekly rainfall, weekly hours leaf wetness, timing of fungicide applications

Disease severity (% leaf area affected) was determined on a plot basis by taking the average of two estimates taken on the centre plot row 1 m from the plot edge on both sides of the plot. Figures 2-4 summarise disease readings and yield components of the 6 released varieties and a highly Stemphylium blight susceptible breeding line.

Rust development started early in the season and high rust incidences were noted, particularly on the rust susceptible variety Fiesta. Disease severity readings on 10 August showed a large reduction of rust following the fungicide applications, but no effect of mancozeb on Stemphylium blight (Figure 2). The large differences in Stemphylium blight severity observed among genotypes in the LPFS disease screening trial was also evident in this trial with the breeding line AF11212 showing a very high degree of susceptibility.

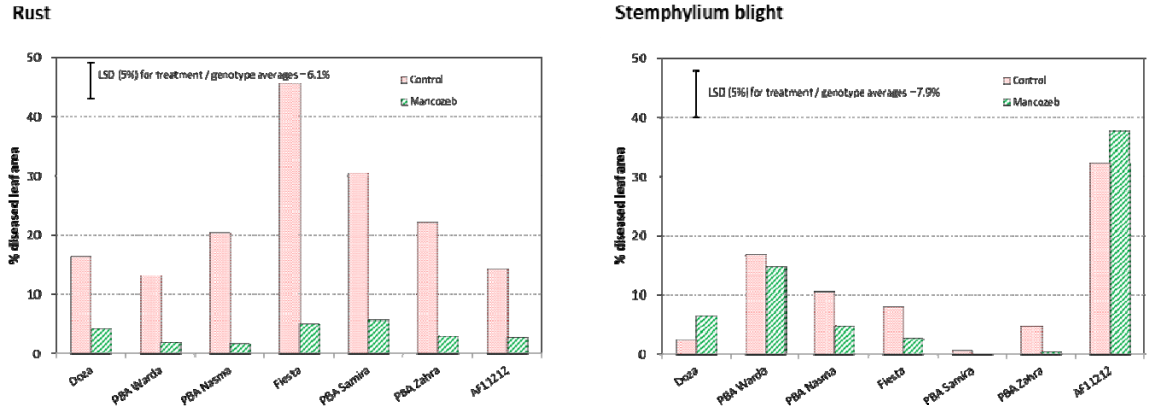

Figure 3. Faba bean disease tolerance trial, Liverpool Plains Field Station, 2016. Rust and Stemphylium blight severity (% leaf area affected) on 10 August.

Later in the season Stemphylium blight symptoms remained largely at the base of the plants and did not progress to younger leaves. High rainfall during the second half of August and early September favoured further spread of rust and, especially, a rapid development of chocolate spot. Mancozeb applications kept rust at low levels, but control of chocolate spot was unsatisfactory (Figure 3).

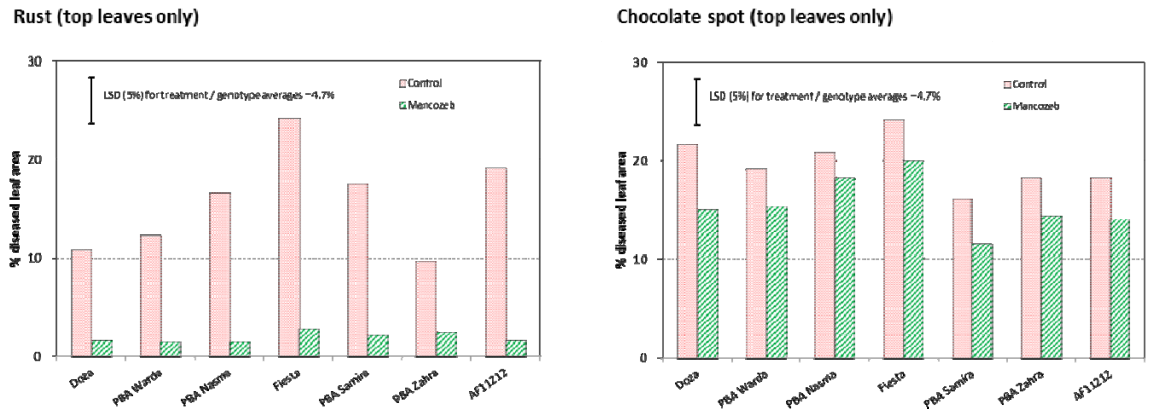

Figure 4. Faba bean disease tolerance trial, Liverpool Plains Field Station, 2016. Rust and chocolate spot severity (% leaf area affected) on 27 September.

Averaged over the 7 entries, the fungicide applications resulted in a 65% increase of yield. The largest increase in yield was on the highly rust susceptible variety Fiesta, but - surprisingly - significant yield gains were as well recorded on varieties with a high level of rust resistance like Doza, PBA Warda and PBA Zahra. No effect of the fungicide application on seed weight was evident. It is interesting to note that the advanced breeding line AF11212, which was severely affected by Stemphylium blight early in the season, ended as one of the better yielders of the trial with and without fungicide application. Proper Stemphylium blight yield loss experiments are needed before definitive statements can be made, but this could indicate that early infection by Stemphylium blight may not have a large impact on final grain yield.

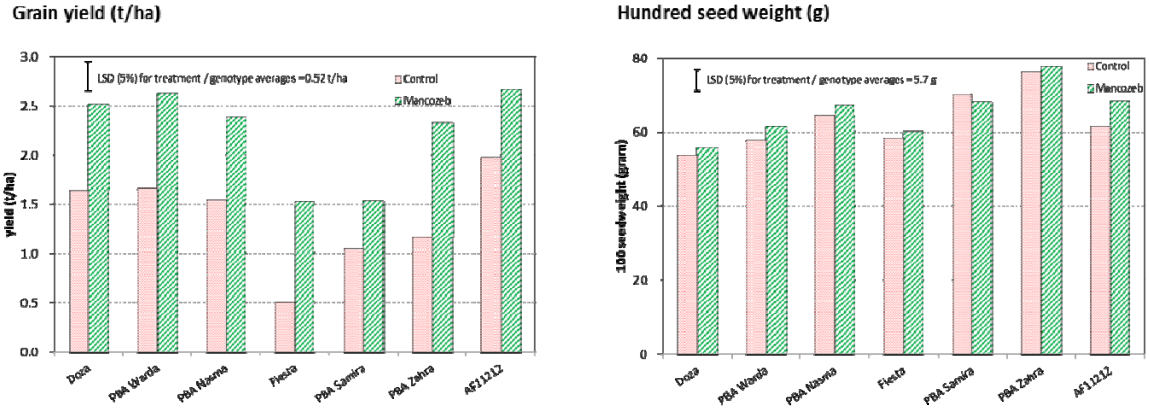

Figure 5. Faba bean disease tolerance trial, Liverpool Plains Field Station, 2016. Grain yield and seed weight.

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Minimising risk of disease in 2017 chickpea crops

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Key words

Chickpea, Ascochyta, Botrytis, Phytophthora, Sclerotinia, waterlogging, management

GRDC codes

DAN00176, DAN00212, DAN00172, DAN00177

Take home message

2016 conditions were very conducive to Ascochyta, Botrytis, Phytophthora and Sclerotinia diseases in chickpea crops throughout the GRDC Northern Region.

Large amounts of inoculum of these pathogens will be available to infect 2017 chickpea crops.

Strategies described in this paper will reduce the risk of these diseases; the more strategies employed, the greater the benefit for chickpea growers in 2017.

Background

Following high incidences of diseases (Ascochyta, Phytophthora, Sclerotinia and Botrytis) in 2016 chickpea crops throughout NSW and Queensland, there will be large amounts of inoculum to infect 2017 chickpea crops.

This paper describes strategies that will reduce the risk of each of these diseases. Some of these strategies are based on local and international field experiments; others are based on observations of reduced disease in 2016 crops. The more strategies employed, the greater the benefit for chickpea growers in 2017 and beyond.

Ascochyta blight, AB, Asco (fungus *Phoma rabiei* previously called *Ascochyta rabiei*)

Ascochyta inoculum will be present in four forms:

1. Ascochyta infected chickpea residue being discharged out the back of headers or spread by floods and surface water;
2. Seed internally infected by the fungus (a consequence of pod infection);
3. Seed contaminated externally with infected chickpea residue during harvest and handling;
4. Volunteer chickpea plants infected over summer and autumn.

The following will reduce the occurrence and impact of Ascochyta Blight in 2017 chickpea crops.

- Grow varieties with improved AB resistance (experiment/observation): These varieties will have less disease and require fewer fungicide sprays.
- Burn cereal stubble (this holds AB inoculum, observation): Infected chickpea residue discharged during harvest of 2016 crops blows onto paddocks that are intended for chickpeas in 2017; most of these will have had a cereal crop in 2016 (or 2015).
- Remove volunteers (observation): Volunteer chickpea plants infected with Ascochyta will provide inoculum even if the volunteer plants are killed with herbicide. Controlling volunteers early will restrict their size and limit the amount of inoculum they can produce.

- Treat all planting seed (experiment): Proper treatment of seed with a registered fungicide will control both internally borne Ascochyta and external contamination.
- Sow later in planting window (experiment/observation): This reduces the number of infection events.
- Wider rows 66cm+ (experiment/observation): Wide rows improve airflow through the crop leading to more rapid drying after a rain event or dew. They also delay canopy closure and improve penetration of fungicides later in the season.
- Tyne openers rather than disc (observation): 2016 observations of less Ascochyta where crops had been sown with tynes is thought to reflect burial and movement of Ascochyta inoculum away from the emerging seedlings.
- Double crop sorghum, cotton (experiment/observation): Stress and high biomass favour Ascochyta. 2016 crops double cropped into sorghum or cotton residue were less affected by waterlogging and did not produce the biomass of chickpeas sown into winter cereal or long fallow paddocks.
- Fungicide before 1st post emergent rain event, even PBA Seamer(ф) (experiment/observation): 2016 crops that had an early preventative Ascochyta fungicide had less disease than crops that were not sprayed until after the disease was detected. Even though PBA Seamer(ф) is rated resistant to Ascochyta, growers are urged to apply a preventative fungicide because: (a) the large amount of inoculum will increase disease pressure, (b) it safeguards against changes in the Ascochyta pathogen that are more aggressive or virulent on PBA Seamer(ф) and (c) it insures against contamination of PBA Seamer(ф) crops with plants of varieties with lower or no Ascochyta resistance eg PBA HatTrick(ф), PBA Boundary(ф) or Kyabra(ф) (varietal purity is still a major issue in our chickpea industry).

Phytophthora root rot, PRR (fungus-like Oomycete *Phytophthora medicaginis*)

Phytophthora inoculum will be present in three forms:

1. Chickpea plants that had PRR in previous seasons (up to 10years back);
2. Other hosts e.g. medics, lucerne, and other leguminous plants including sulla (*Hedysarum* spp) and sesbania (*Sesbania* spp) in which Phytophthora can survive and multiply;
3. Soil and water containing PRR infected material and survival structures (oospores, chlamydospores).

The following will reduce the risk of PRR in 2017 chickpea crops.

- Avoid PRR high risk paddocks where annual or perennial medics have been a component of pastures and where PRR has occurred in the past chickpea or lucerne; the oospores of *Phytophthora medicaginis* can survive for more than 10 years.
- Avoid paddocks with areas prone to waterlogging although the conditions which induce waterlogging may not occur every year.
- Avoid paddocks exposed to water flow from previous chickpea or medics areas; PRR infected material and survival structures can be spread though water movement to neighbouring paddock/s.
- Metalaxyl-based seed dressings are registered for PPR, but they are relatively expensive and provide only 6-8 weeks protection after sowing.
- Grow a variety with the highest level of resistance, particularly in medium-high risk situations, such as where medics, chickpea or lucerne crops have been grown in the past 5-6 years.

Sclerotinia stem and basal rot (fungi *Sclerotinia sclerotiorum*, *S. minor*)

In the GRDC northern region, *Sclerotinia* spp infect chickpea plants two ways (a) Sclerotia germinate directly in or on soil and invade the plant through root or basal stem tissue, producing Sclerotia on and within the basal stem tissues, (b) Sclerotia germinate indirectly, produce apothecia at ground level and these release air borne ascospores (carpogenic germination) that infect plant parts higher in the canopy. In most seasons we only see direct germination because carpogenic germination needs cool moist conditions. In August/September 2016, Sclerotinia disease was very common in chickpea crops in north western NSW and southern QLD due to high levels of canopy leaf wetness and favourable temperatures. Importantly, every case of Sclerotinia involved carpogenic germination ie infection at mid canopy meaning that the Sclerotia formed on and inside the chickpea stems would have been captured during harvest. This led to problems at receival because the cylindrical Sclerotia formed inside the stems resembled ryegrass ergots and some loads were rejected or docked. Sclerotinia inoculum will be present in several forms:

1. Sclerotia spread by floods and surface water;
2. Sclerotia admixed with chickpea seed and introduced into 2017 chickpea paddocks during planting;
3. Sclerotia in canola residue in paddocks intended for chickpea in 2017; large Sclerotia can survive for up to 10 yr;
4. Sclerotia in weed hosts in paddocks intended for chickpea in 2017;
5. Sclerotia already present in paddocks with a history of broadleaf crops and recent Sclerotinia outbreaks.

The following will reduce the risk of Sclerotinia in 2017 chickpea crops.

- Grow varieties with lowest susceptibility: Sclerotinia basal rot was assessed in field trials at Wagga Wagga in 2014 and 2016 which led to the following tentative ratings:
- Very susceptible: PBA Maiden(Þ)
- Susceptible: Ambar(Þ), Genesis™ 090, Neelam(Þ), PBA Slasher(Þ), PBA Striker(Þ), PBA Monarch(Þ)
- Moderately susceptible: PBA Boundary(Þ), PBA HatTrick(Þ), PBA Seamer(Þ)
- Avoid paddocks with a history of Sclerotinia. Paddocks with a history of Sclerotinia will already have a population of viable sclerotia before the crop is sown and these are a disease risk. A frequent history of the disease also indicates that the environment is also most likely favourable for Sclerotinia to develop. Be aware that even adjoining paddocks can be at risk, due to movement of air-borne ascospores of the Sclerotinia fungus.
- Avoid paddocks with a history of canola. Canola is a very good host for Sclerotinia stem rot. Experience in southern NSW has shown that the number of sclerotia in the soil can build up very quickly when canola is frequent in the cropping rotation.
- Avoid paddocks with a history of broadleaf weeds. The collective host range of the Sclerotinia fungi (*Sclerotinia sclerotiorum, S. minor*) exceeds 400 plant species, mostly broadleaf plants. Weeds can be important in maintaining sclerotial populations in paddocks, even when the frequency of broadleaf host crops in the rotation is low. Broadleaf weeds such as capeweed, shepherds purse and variegated thistle are just some common hosts for Sclerotinia.
- Sow within the planting window. Observations from field trials at Wagga Wagga suggest that early sown chickpea is more prone to developing symptoms of Sclerotinia infection; this includes both direct infection and canopy infection from air-borne spores. Plots sown within the

recommended sowing window developed significantly less disease. Dense crop canopies from an early sowing also favour Sclerotinia stem rot later in the season.

Botrytis seedling disease, BSD (fungus *Botrytis cinerea*)

BSD and Botrytis Grey Mould, BGM are caused by the same fungus, *Botrytis cinerea*, but they are very different diseases. BSD is a seed-borne disease that can occur at any temperature and under any conditions. BSD can ONLY occur if pods of chickpea crops from which the seed came were affected by BGM. BSD is readily controlled with the standard chickpea seed treatments. BSD inoculum will be present in two forms:

1. Seed from pods infected with *B. cinerea* during a prior BGM outbreak.
2. Primary infections of BSD (ie from *B. cinerea* infected seed); primary infections lead to secondary infection of initially healthy seedlings through root contact.

The following will reduce the risk of BSD in 2017 chickpea crops.

- Treat all planting seed: Field trials conducted in 2011 at Moree, Narrabri and Breeza using two *B. cinerea* infected seed lots from the 2010 BGM epidemic, showed treating chickpea seed with registered seed dressings controlled BSD, improved crop establishment and increased yield but proper coverage and rate were essential.
- Avoid using *B. cinerea* infected seed: Even though seed treatment controls BSD, Botrytis infected seed will have lower vigour than non-infected seed.

Botrytis grey mould, BGM (fungus *Botrytis cinerea*)

BGM is an air-borne foliar disease active ONLY when temperatures warm up towards spring (ca 15°C). It is more prevalent in the warmer regions of the north, where significant crop losses can occur in wet winters and springs as occurred in 2016. BGM is controlled with foliar fungicides; seed treatment is ineffective. Testing chickpea seed from the 2016 harvest at Tamworth has found that half the seed lots tested to date (December 2016) are internally infected with Botrytis. Not treating this seed will lead to BSD (but will have no impact on BGM in 2017). *Botrytis cinerea* is ubiquitous, has a wide host range (over 138 genera in 70 families) and is a good saprophyte, meaning it can survive, grow and sporulate on just about any dead plant tissue. The fungus readily produces air borne spores and some isolates form sclerotia. This means that inoculum of BGM is always present and if conditions favour BGM, it will occur irrespective of what has happened earlier in the chickpea season.

The following will reduce the risk of BGM in 2017 chickpea crops.

- Paddock selection: Avoid planting chickpeas next to paddocks where BGM was an issue the previous season. As for Ascochyta blight, chickpeas should be grown as far away from paddocks in which BGM was a problem as is practically possible. However, under conducive conditions, this practice will not guarantee that crops will remain BGM free, because of the pathogen's wide host range, ability to colonise dead plant tissue, and the airborne nature of its spores.
- Sow later: If long-term weather forecasts suggest a wetter-than-normal 2017 season (La Nina) consider sowing in the later part of the planting window as this will reduce biomass production; BGM is favoured by dense canopies.
- Wider rows 66cm+: Wide rows improve airflow through the crop leading to more rapid drying after a rain event or dew. They also delay canopy closure and improve penetration of fungicides later in the season.
- Foliar fungicide: In areas outside central QLD, spraying for BGM is not needed in most years. However, in seasons and situations favourable to the disease, a preventative spray of a

registered fungicide immediately prior to 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 chickpea BGM have eradicant activity, so their application will not eradicate established infections. Consequently, timely and thorough application is critical.

Waterlogging

Waterlogging (WL) and other stresses can reduce resistance and efficacy of management. Plants exposed to environmental stresses have altered architecture, metabolism and elongation; these reduce the plant's ability to maintain resistance and re-shoot post disease infection. This was evident across chickpea crops in 2016 with increased severity of AB on resistant lines (including PBA HatTrick(b), MR) when under WL stress. Preventative fungicide spray application on stressed, disease prone areas is critical to reducing yield loss.

There are currently no released varieties with significantly improved waterlogging (WL) tolerance; further studies are currently being carried out to exploit potential for improvement in conjunction with PRR resistance. During the 2016 season the northern growing region reported significant crop losses due to PRR. Surveying and quantitative PCR testing of soil samples collected from a number sites across this region concluded that both PRR and waterlogging were involved in plant death at various growth stages. Differentiating WL and PRR crop damage is difficult, often WL is incorrectly identified as PRR.

Distinguishing WL from PRR

- Water logging symptoms occur 1-3 days post flooding compared to a minimum of 7 days for PRR. Both WL and PRR can have similar above ground symptoms with red/yellowing, wilting, and death of plants. However, WL affected plants often succumb too quickly to have red/yellowing or lower leaf drop as always occurs with PRR. PRR symptoms may be delayed if temperatures are cool and soil moist. Waterlogging is a result of lack of oxygen to roots; PRR is the result of an organism killing roots. Waterlogging is thus more common and pronounced during warmer periods because (i) warm water cannot hold as much oxygen as cold water, and (ii) during warm weather, plants grow faster and thus need more oxygen.
- Affected whole plants need to be examined shortly after prolonged rain or flood event (1-3 days). Are the plants easy to pull out? PRR affected plants have little to no lateral roots and offer no resistance when pulled. Initially, WL affected plants have intact lateral roots and will not pull easily. Note: waiting longer than7 days to do the pull test on WL affected plants allows opportunistic soil fungi to decay lateral roots leading to misidentification as root rot.
- PRR infected plants may have dark brown or black lesions on the tap root. Often such lesions extend above ground level forming a slightly sunken canker with a distinct junction with healthy stem tissue above.
- Plants are most susceptible to WL at flowering and early pod fill unlike PRR which can occur at all growth stages.

The following will reduce the risk of waterlogging in 2017 chickpea crops.

- Avoid poorly drained paddocks and those prone to waterlogging.
- Sow later if the weather forecast for 2017 predicts a wetter-than-normal early-to-mid season. Evidence suggests that in chickpea and other crops early vigour associated with plants in the

early vegetative phase will re-shoot and recover root growth more efficiently reducing plant death.

Additional Information

Further information on chickpea disease management can be found at the Pulse Australia website www.pulseaus.com.au and in the NSW DPI 2017 Winter Crop Variety Sowing Guide.

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Chickpea Ascochyta – Further evidence that varieties differ in reaction of pods

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Key words

Chickpea, Ascochyta, management

GRDC codes

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Take home message

The susceptibility of pods to Ascochyta blight is important as infection can cause pod abortion and blemish or kill seed; infected seed can lead to downgrading of grain, furthermore infected seed is a future inoculum source.

A 2016 field trial confirmed that chickpea varieties differ in pod reaction to Ascochyta; varieties with higher levels of resistance to vegetative plant tissues e.g. PBA Seamer(Φ) had less disease on their pods.

However, as all varieties can get pod infection (albeit at different proportions), in Ascochyta conducive seasons pods need to be protected with fungicides.

Background

Knowing the susceptibility of chickpea pod tissue to Ascochyta blight (caused by *Phoma rabiei* formerly known as *Ascochyta rabiei*) is important because if pods get infected early in their development they will abort; if fully developed pods get infected near the peduncle (as many do because the calyx holds water), they will abort; or the seed will get infected and is killed or the seed becomes infected, but remains viable and is a potential source of inoculum to initiate an epidemic. Further, if Ascochyta lesions are detected on desi or kabuli kernels and the incidence exceeds 1% by weight, the load will be downgraded or rejected.
http://www.pulseaus.com.au/storage/app/media/markets/20160801_Pulse-Standards.pdf

Current Australian chickpea varieties and advanced breeding lines differ in susceptibility of their vegetative plant tissues to Ascochyta Blight (Moore et al, 2016). However, the chickpea industry believes that pods of all varieties are equally susceptible to Ascochyta (see http://www.grdc.com.au/GRDC-FS-ChickpeaDiseaseManagement). The 2011 Tamworth chickpea Ascochyta management trial, VMP11 suggested that may not be the case - anecdotal evidence indicated varieties with higher levels of resistance to Ascochyta e.g. Genesis™ 425 had less disease on their pods and scientific evidence was obtained by the 2014 Tamworth chickpea Ascochyta yield loss trial, VMP14. VMP14, which was inoculated before flowering, provided data on susceptibility of pods of ten genotypes consisting of released varieties and advanced breeding lines ie CICA1007, (C1007), CICA1211 (C1211), Genesis™425 (G425), Genesis™Kalkee (KAL), PBA Seamer(Φ) (SEA, coded as CICA0912 in Figure 1), PBA HatTrick(Φ) (HAT), PBA Monarch(Φ) (MON), PBA Boundary(Φ) (BOU), Kyabra(Φ) (KYB), and Jimbour(Φ) (JIM). The genotypes fell into 4 susceptibility groups with no differences between entries within a group but significant differences between genotypes in different groups. The four groups from least to most susceptible were (C1007, SEA, G425), (BOU, HAT, KAL, MON), (C1211) and (JIM, KYB) (Fig. 1).

A criticism of VMP14 is that the data could be confounded, because the plots (JIM and KYB) with the most infected pods and the greater number of lesions were also those that had the highest levels of Ascochyta in the vegetative stage. We reasoned (Moore at al., 2015) there was sufficient inoculum pressure in VMP14 that all pods of all genotypes in the trial would have been exposed to the same level of inoculum. Nevertheless, the fact remains that plants had been exposed to at least five infection events during the vegetative phase and that could have affected resistance of genotypes and/or inoculum pressure within a plot. The 2016 trial, reported here, addressed these concerns by protecting plants with foliar fungicide during the vegetative stage and by sampling pods after one post-inoculation infections event.

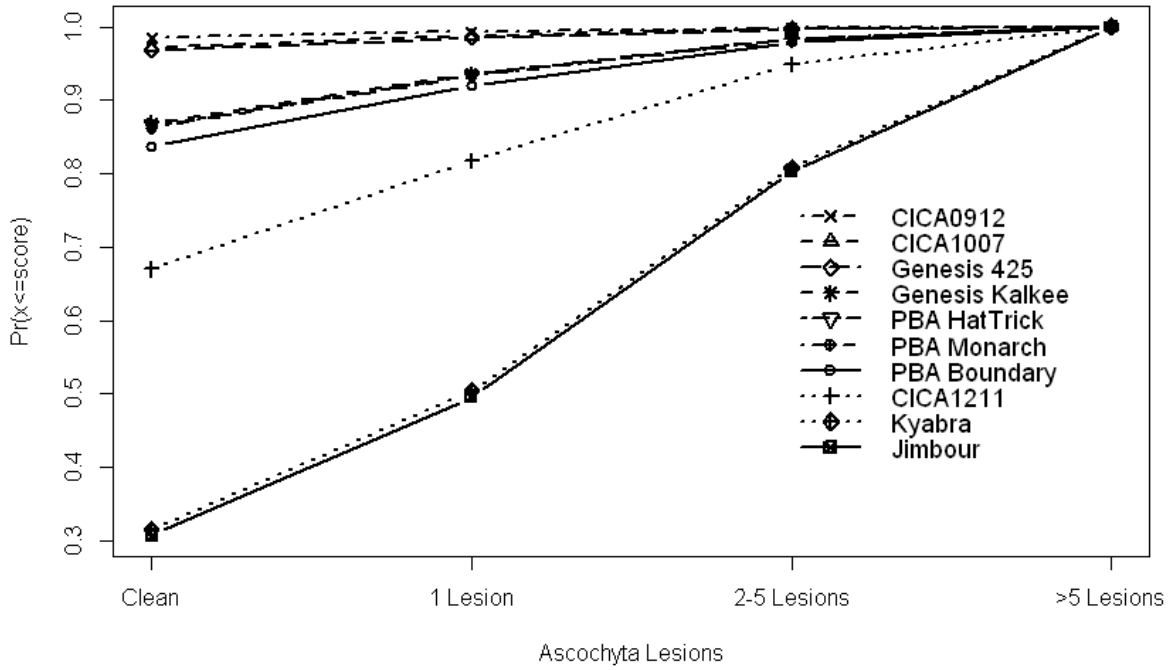

Figure 1. Predicted cumulative proportions of pods across four disease severity categories of Ascochyta lesions for the ten chickpea genotypes in the 2014, VMP14 trial

Methods

The trial (POD16) was sown into burnt barley stubble on 18 May 2016 using tyne openers on 50cm row spacing in plots 2m wide by 10m long. Granulock® Supreme Z (50kg/ha) and liquid Rhizobia were applied at sowing with Gesatop® 600 SC applied PSPE. There were five varieties PBA Seamer$^{\Phi}$ PBA Boundary$^{\Phi}$, PBA HatTrick$^{\Phi}$, PBA Monarch$^{\Phi}$ and Kyabra$^{\Phi}$ coded as above and four replications. Plants were protected from Ascochyta infection with eight applications of 1.0L/ha chlorothalonil (720g/L active) applied before rainfall, the first application on 4th July and the last on 14th October. On 30th October when the desi varieties were at 50-60% podding and PBA Monarch$^{\Phi}$ was at 40-50% podding, the trial was inoculated during a rain event with a cocktail of 20 isolates of *P. rabiei* containing 550,000 conidia/mL of water and applied at 100 L/ha; there were four application passes giving a total of 2.2million conidia/mL. From the start of inoculation (6pm) to when the rain stopped at 7am 31 October, 17mm fell. On 10th and 14th November, 16.4mm and 12.8mm were recorded, respectively, this rainfall provided two potential post-inoculation secondary infection events. On 18th November, from each plot in Reps 1-3, one branch was collected from 50 plants at random (Rep 4 was severely affected by Phytophthora root rot and was not sampled).

Ascochyta assessment and statistics

Samples were air dried in glasshouse for 1 day, pods removed and sorted into four disease severity classes based on their Ascochyta status: clean = no Ascochyta lesions; 1 lesion = pods with a single lesion; 2-5 lesions and >5 lesions. A lesion was not called Ascochyta unless pycnidia could be seen either with the naked eye or under a low power dissecting microscope. For each variety the number of pods falling into each of the four Ascochyta classes was analysed using proportional odds logistic regression, implemented using the "polr" function of the r MASS package Venables & Ripley (2002). Differences between varieties were assessed by comparing the coefficients of the model for each variety. A 95% confidence interval (CI) for each coefficient was calculated. Two varieties differ in disease severity if their respective CI's do not overlap.

Results

2016 results: To limit the potential effect of secondary infection via inoculum generated from susceptible vegetative tissue, the pod samples were harvested 18 days after inoculation. At this early time point there were large differences in pod infection among the genotypes. Only 1.3% of KYB pods were clean (no disease), whereas 22.8% of SEA pods had no Ascochyta (Table 1). Not only did KYB have a greater proportion of Ascochyta infected pods, but these pods were more severely diseased with most (63.7%) infected pods having more than five Ascochyta lesions; this compares with only 10.2% of infected SEA pods having more than five lesions (Table 1).

Analysis showed with the exception of BOU and HAT, varieties were significantly different (P = 0.05) with the ranking from least to most susceptible being SEA < MON < BOU = HAT < KYB (Fig. 2).

2014 and 2016 results: All varieties in POD16 had more pods infected with Ascochyta than the same varieties in 2014. This is believed to reflect higher disease pressure in 2016 resulting from inoculation with 2.2million conidia/mL and very conducive conditions (total 46.2mm rain in 3 rain events). Nevertheless, the ranking of varieties was the same as in 2014 (Fig. 1, Fig. 2, Table 1) and the conclusions reached were the same.

Table 1. Percentages of pods in four Ascochyta disease severity categories for five varieties in 2016 vs 2014

Genotype	%Clean	%1 Lesion	%2-5 Lesions	%>5 Lesions
SEA 2016	22.8	15.0	52.0	10.2
SEA 2014	*98.5*	*1.0*	*0.3*	*0.3*
MON 2016	16.5	12.9	51.4	19.3
MON 2014	*86.2*	*7.8*	*3.3*	*2.8*
BOU 2016	11.4	10.1	48.3	30.2
BOU 2014	*84.3*	*5.5*	*6.3*	*4.0*
HAT 2016	10.1	9.8	47.0	33.2
HAT 2014	*86.2*	*9.3*	*4.0*	*0.5*
KYB 2016	1.3	3.1	31.9	63.7
KYB 2014	*33.8*	*15.5*	*30.5*	*20.3*

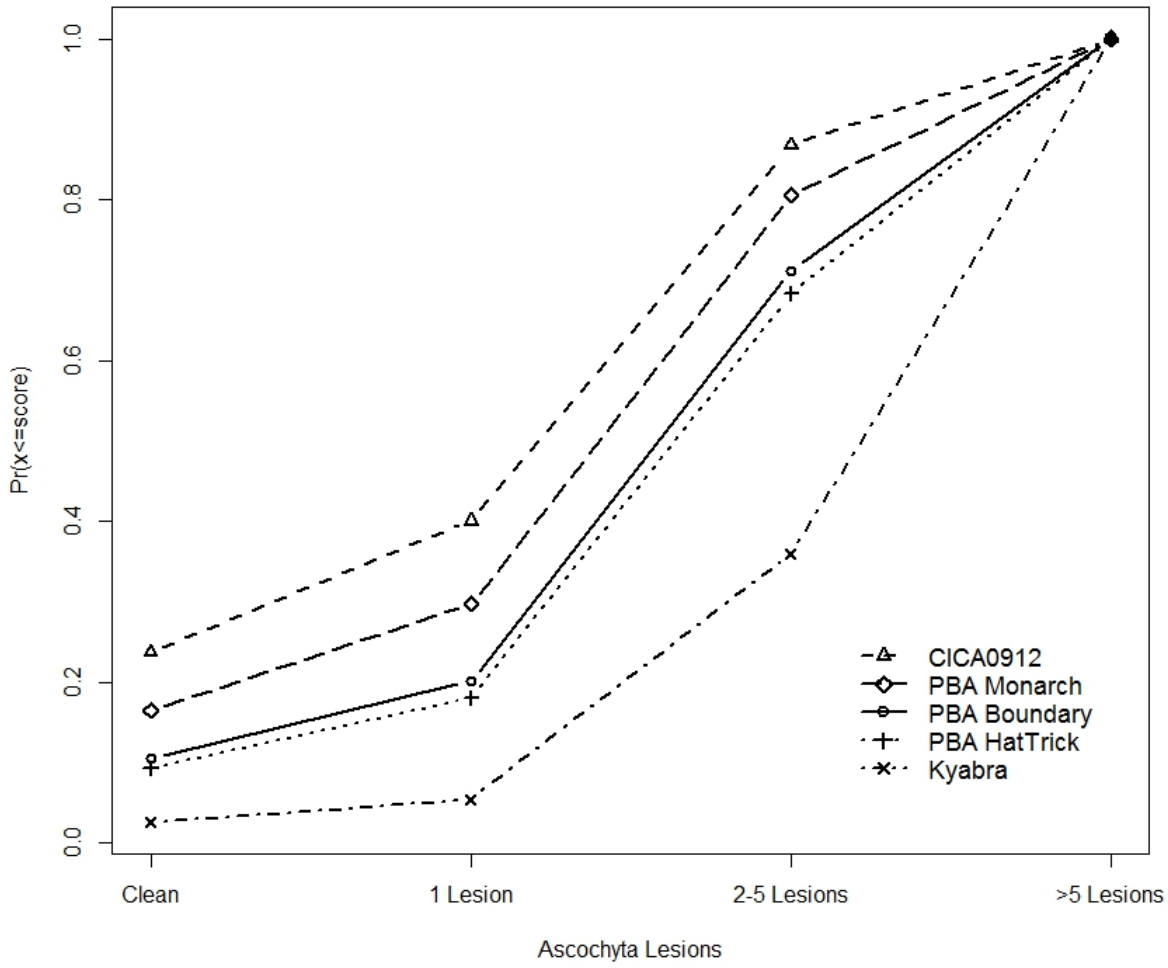

Figure 2. Predicted cumulative proportions of pods across disease severity categories of Ascochyta lesions for the five chickpea varieties in the 2016 trial. (CICA0912 is PBA Seamer(t))

Key pod infection findings of POD16 were:

- Varieties differed in the relative proportion of severely infected pods 18 days after inoculation, with SEA < MON < BOU = HAT < KYB
- This ranking agrees closely with current Ascochyta variety ratings for vegetative tissues
- From a management perspective, all varieties can get pod infection (albeit at different proportions); therefore in Ascochyta-conducive seasons pods need to be protected with fungicides

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Disease risk prediction for Phytophthora root rot of chickpeas: inoculum detection problems

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Key words

Phytophthora root rot, risk management, inoculum measurement, PreDicta B®

GRDC code

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Take home message

- *Phytophthora medicaginis* (Pm) inoculum concentrations decline to low levels (within 6-12 months) of a diseased crop and the distribution becomes more uneven
- Resting populations (oospores) can be below detectable levels based on both soil DNA and isolate baiting methods
- These factors limit the ability of PreDicta B® to identify paddocks which have a significant disease risk
- The Pm test is useful for disease diagnosis when the pathogen is active and inoculum decline has not taken place

Note: the SARDI PreDicta™ B test for *Phytophthora medicaginis* is under development and is not yet available commercially.

Phytophthora medicaginis detection in soil

Phytophthora medicaginis, the cause of chickpea Phytophthora root rot (PRR) is endemic and widespread in the northern grains region. Under conducive conditions, PRR can cause 100% loss. The pathogen survives from season to season on chickpea volunteers, lucerne, native medics, sulla and as resting structures (oospores) in roots and soil. It is known that Pm inoculum concentrations is difficult to detect and quantify in paddocks when a susceptible host such as chickpeas is not present (Dale and Irwin, 1990).

A PreDicta B soil DNA test has been developed by the South Australian Research and Development Institute (SARDI) to quantify the amount of Pm DNA in soil samples and so provide a measure of the amount of Pm inoculum (infected root tissue and oospores) in paddocks. We report on three seasons of studies to assess the capability of this test to:

1. Detect Pm in soil from commercial paddocks
2. Predict the risk of PRR disease and potential yield losses in chickpea

Methods

Ability to detect Pm in paddock samples: Soil samples were collected during winter-spring period from fields in northern NSW and southern QLD in 2013, and from central (16) and south-western Queensland (10), and Victoria (7) in 2014. All paddocks included chickpeas in the rotation but not all had chickpeas in the previous year.

Eight sites were sampled per paddock using with 10 soil cores (15 long 1 cm wide cm AccuCore soil corer). At each site 10 cores were collected every 20 – 25 paces along a 'W' collection pattern (total

distance 200 – 250 m per sample site). If soil conditions were too dry, a 15 cm long by 6 cm wide trowel tapering to 2 cm was used to sample. Soil samples were stored in sealed plastic bags at 5°C.

After sieving (4 mm aperture), a 400 g sub sample was sent to SARDI for DNA analysis the remainder of each sample was used for baiting of the pathogen using a glasshouse based technique. Seedlings (cv. Sonali) were assessed for disease (chlorosis, stem cankers, death) three times a week. Stem tissues were plated to isolate Pm. Cultures with Phytophthora like growth on cornmeal agar were plated on low strength V8 agar and colony morphology, oospore production and oospore size used to identify Pm like cultures. Isolation of Pm was attempted from all treatments that produced chlorosis followed by the appearance of Pm like stem cankers or seedlings with poor growth. After six weeks the experiment was terminated. To fulfil Koch's postulates on putative Pm isolates, seedlings of the susceptible chickpea cv. Sonali were inoculated in controlled environment experiments.

Detection capability across a range of concentrations: A Pm concentration:DNA yield series was prepared using a Pm isolate (943c-1) grown on plates of low strength V8 agar then prepared as a oospore-mycelium solution with distilled water at 1752 oospores/mL (average of five separate sample counts). The required volume of solution containing 0, 100, 500, 1000, 2000, 4000, and 8000 oospores was then pipetted into 400 g of dry sand and distilled water added to bring the total volume of each solution to 5 mL, with three replicates prepared. The samples were sent to SARDI for Pm DNA analysis.

Disease and yield loss prediction trials: In 2014, 2015 and 2016 disease and yield loss prediction trials were carried out. A range of Pm levels were established by applying, different rates of oospores (a mixture of 10 isolates) in-furrow at seedling to four row plots. At sowing or early in the season soil cores (150 mm depth cores, in row coring) were collected from the two middle rows of each plot and pooled and analysed for soil Pm concentration by SARDI. During the each season PRR disease assessments (% infected plants, or row length of severely infected plants) and grain yields were measured from the two middle rows of each plot. The trials were also soil sampled at the end of season as described previously. The 2015 and 2016 trials had four row buffer plots around each plot to limit spread between plots. Irrigation treatments were watered with dripper tape delivering between 0.6 to 0.7 mm/hr.

Ability to monitor Pm concentrations in paddocks: To develop sampling recommendations, Pm concentrations were assessed on three farms (Coonamble NSW, Moree NSW, Goondiwindi QLD) where PRR had been an ongoing problem, "Hotspots" were marked and GPS recorded.

Four samples were collected from each hotspot area following a W collection pattern (32 points along the pattern, each point 6 m apart, using a 150 mm AccuCorer). At each point cores were sampled from a single stubble row, with each core for each separate sample taken 2-3 cm apart. Low lying areas of paddocks where pooling following rainfall occurred (below contour banks, low areas of paddocks, dips) were also sampled and raised or uniform areas were also collected, these areas provided three 32 core 'low area' samples and three 32 core 'high area' samples from each field, their GPS positions were also marked. Using this method 12 paddocks were sampled in April 2016, another four paddocks were also sampled with either hotspot or low-high samples collected. In Nov and Dec 2016 all hotspot sites were resampled, all low-high sample sites were revisited and samples collected from paddocks in chickpeas in 2016 showing any disease problems.

For the April samples three soil samples from each hotspot and all low-high samples were sent for analysis to SARDI. The fourth hotspot sample was assessed for Pm in a glasshouse baiting experiment (5 reps, cv. Sonali grown in a soil:sand mix) as described previously. At the end of the baiting experiment the soil-sand media in each cup was sent to SARDI for analysis.

Hotspot sites in Coonamble and Goondiwindi were resampled in Nov to compare with April results and for paddocks in chickpeas, the low and high areas were also inspected and soil samples collected if any disease symptoms were observed.

Results and discussion

Ability to detect Pm in paddock samples: The 2013 and 2014 collected soils showed a similar pattern with most samples (which had positive DNA results also yielding Pm cultures 2014: 9/11, 82%; 2015: 8/9, 89%) and with most samples which had negative DNA results not yielding Pm cultures (2014: 36/37, 97%; 2015: 33/34, 97%). There were two false negatives, whereby the DNA method did not detect Pm, but the soil sample yielded Pm isolates. If within sample variability is high, the lack of DNA detection may be due to low concentrations in the sub-sample submitted for DNA analysis. Both sets of samples also had some cases of false positives, possible explanations for this is that more time may be required for symptoms to develop during baiting, or that the pathogen had died but some DNA had been detected.

Detection capability across a range of concentrations: The experiment showed increasing DNA yields from an increasing pathogen concentration, although the spread among replicates was quite large for the three highest concentrations (Figure 1). It was also notable that for the lowest concentration 0.25 oospores/g (100 oospore solution in 400 g sand) that yields were variable, values for the three replicates were 0, 261 and 858 copies/g sand. It is possible that the small amounts of DNA present in low concentration samples, such as these, may have degraded during transportation to SARDI for analyses and lead to the nil detection in one replicate. Further work is required in this area but this single set of results suggests that the detection of Pm DNA at low concentrations (≤ 0.25 oospores/g sample) may be variable and could deliver nil detection values.

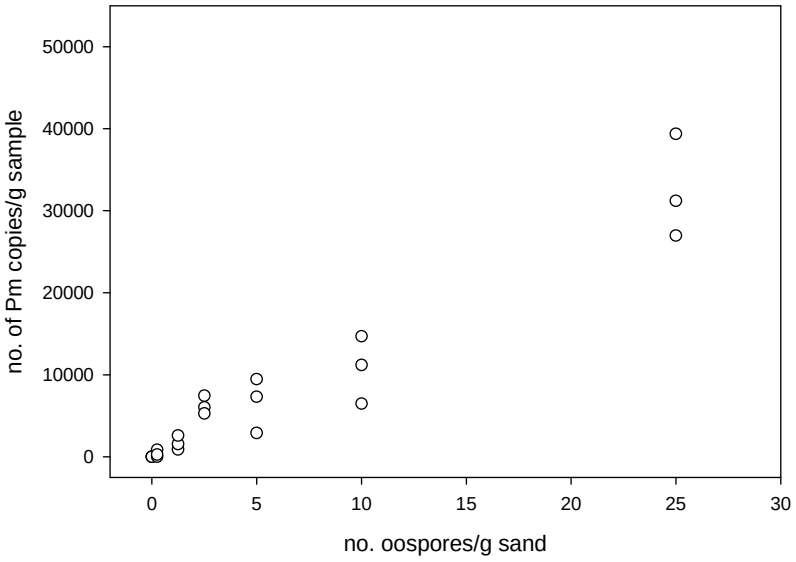

Figure 1. Plot of three replicate sample of Pm oospore-mycelium in sand at a range of concentrations against the yield of Pm copies/g of sample.

Disease and yield loss prediction trials: ability to predict average disease and average yield loss: The relationships between Pm DNA values and disease or yield correlations for the three trials are summarised in Table 1. For 2014 with cv. Sonali there were relatively weak correlations between the early season soil Pm DNA concentrations and PRR disease (r = 0.46) and chickpea yields (r = - 0.37), but for the 2015 with var. Yorker(Þ) trial Pm DNA values provided a common central relationship across data from both irrigation treatments for both disease and yield. The 2016 trial with cv. Yorker(Þ) provided a poor relationship between Pm DNA values and both disease and yield. The high

r values for PRR disease measurements and yield in each trial supported the assumption that the yield losses were principally due to PRR disease.

Table 1. Correlations r values for early season or sowing Pm DNA values, PRR disease and yield of three experiments (DNA14 (2014), HMDNA15 (2015) and HMDNA16 (2016).

Trial date	Post sowing or early season Pm DNA values		PRR disease
	PRR disease	Yield	Yield
2014	0.46	-0.37	-0.86
2015	0.82	-0.77	-0.83
2016	0.17	-0.22	-0.70

Ability to consistently detect Pm DNA in yield loss trials on a plot by plot basis: In each of the three seasons there were a number of plots where no Pm DNA was detected by the qPCR method either at sowing or early in the season or at the post-harvest sample (Table 2). The nil DNA plots included both inoculated and non-inoculated treatments each season. Of the nil Pm DNA early season or at sowing samples, across each of the three trials a proportion (2014 0.79, 2015 0.43 and 2016 0.94) of these then had PRR symptoms, in the majority of cases yield losses were high in these plots (data not presented). The 2016 trial results were unusual with the very large number of nil DNA plots, Pm control samples included for analyses with these samples gave expected DNA values. It is not known why so many 2016 samples gave negative Pm DNA results yet PRR symptoms occurred in the plots. The 2015 trial was the most successful with only 3 of 7 nil DNA plots having PRR symptoms. However, for the postharvest DNA results from 2015 trial 7 plots with PRR had nil DNA values.

Table 2. No of plots in each of three experiments (DNA14 32 plots (2014), HMDNA15 40 plots (2015) and HMDNA16 40 plots (2016)) that had nil Pm DNA results early in the season or at the post-harvest sample and the number of these plots that had PRR symptoms or not.

Time	post sowing or early season Pm DNA values			post harvest Pm DNA values		
Trial date	Total nil DNA values	nil DNA values & nil PRR symptoms	nil DNA values & PRR symptoms	Total nil DNA values	nil DNA values & nil PRR symptoms	nil DNA values & PRR symptoms
2014	14	3	11	2	2	0
2015	7	4	3	11	4	7
2016	33	2	31	-	-	-

Of individual plots with nil DNA results, based on relatively high soil sampling intensities (2.5-3.2 cores/m row length), each season a differing proportion of these then had PRR later in the season. If these findings are extrapolated to a paddock scenario where a single sample-single result from the paddock will be used to assess PRR disease risk, then the probability for nil DNA results but PRR later being observed (a false negative) will range from 0.18 to 0.83. However, as the sampling intensity per unit area of paddocks will be much lower than those of plots in field trials, it may be expected that the probability of a false negative for paddock samples may be higher than those for field trials.

Time of sampling effects on Pm DNA concentrations: The post harvest Pm DNA concentrations did not differ between treatments in 2014 and 2015 trials (not presented), 2016 post harvest results were not available. For DNA14 which include a mid-season sample, for analysis of oospore treatment (P = 0.150), time and oospore trt.*time interaction (P = 0.116), only time was a significant factor (Table 3). The concentrations of DNA at 15 Sep were very high compared to both the early August and Dec post harvest samples. Between 12 and 23 Sep there were large increases in the

number of infected plants (not presented). These results show that when the disease is active, very high soil concentrations of the pathogen are present, but relative to this active period the populations decline rapidly over a three month period.

Table 3. Time effects for Pm DNA concentrations (no. Pm sequences/g soil) for three sample dates in the 2014 Pm inoculum level trial (DNA14) (Time, P < 0.001; lsd 118,466.4)

Time	4 Aug	15 Sep	19 Dec.
Pm DNA	1,561	476,183	8,014

April 2016 paddock inoculum results, detection variability: Six of the 13 paddocks with hotspot soil samples had positive Pm DNA results, all but one of these paddocks were in chickpeas in the 2015 season (Table 4). Of the six paddocks with positive DNA results only two paddocks had all three samples test positive, for another two paddocks (10 and 11) only two samples tested positive and for the other two paddocks (3 and 13) only one of the samples tested positive.

Table 4. April 2016 hotspot sample location, paddock code, prior crop (wh, wheat, cp, chickpea), average hotspot sample Pm DNA, number of positive hotspot samples, April 2016 hotspot sample isolate baiting results (no. cankers, no. of putative Pm cultures) and post-experiment DNA results of baiting media

location	code	2015 crop	Av. Hotspot P. med DNA sequences/ g soil	Hotspot no. + samples	Av. No. Cankers / cup	total no. putative cultures	Av. P. med DNA sequences/ g media
Coonamble	1	wh	0	0/3	0	0	0
Coonamble	2	wh	0	0/3	0	0	0
Coonamble	3	cp	209	1/3	0	0	205
Coonamble	4	cp	0	0/3	0	0	0
Coonamble	5	cp	0	0/3	0	0	0
Coonamble	6	cp	0	0/3	0	0	0
Coonamble	7	cp	0	0/3	0	0	544
Coonamble	8	cp	0	0/3	0	0	0
Goondiwindi	9	cp	1389	3/3	3	6	334767
Goondiwindi	10	cp	1205	2/3	2.8	9	348014
Goondiwindi	11	cp	690	2/3	0.75	2	618706
Goondiwindi	12	cp	2881	3/3	3	7	186981
Moree	13	wh	339	1/3	0	0	0

Given the close proximity (2-3 cm apart) of the cores sampled at each of the 32 points in a hotspot area it was notable the extent of variability in positive DNA results among the three samples. The results for paddocks 10 and 11, and in particular, for paddocks 3 and 13 indicate an uneven distribution of inoculum giving differing results even for closely collected soil samples. The baiting experiment yielded characteristic PRR symptoms and putative Pm cultures for soil samples from the four paddocks with two or three positive samples (Table 4). The post-baiting media DNA results showed large increases in DNA values relative to average hotspot soil results for these four paddock, however, paddocks 3 and 7 also had positive but low value media DNA results although disease

symptoms were not observed during baiting. Conversely, paddock 13 which had one positive hotspot soil sample, had both no disease symptoms or positive post-baiting media DNA result.

The baiting experiment results supported the soil DNA results, including that Pm inoculum was unevenly distributed in these samples. The large increases in baiting media DNA values relative to soil only results, and in particular the positive media DNA results for paddocks 3 and 7 which only had negative soil results, suggest that the baiting process may be useful in raising the DNA values for soil samples which initially have very low inoculum concentrations. Various priming methods have been developed to improve the detection of oomycetes at low concentrations or where the pathogen may be dormant (Wakeham and Pettitt, 2016). However, later season survey results (see Table 6) for paddocks 1, 2, 4 and 6 which had nil disease when baited and nil Pm DNA in the baiting media had PRR symptoms and positive DNA results in Nov of 2016, showed that such a priming method does not show promise for PRR prediction.

April 2016 paddock inoculum results, sample site effects: PRR is often first seen to occur in low lying areas of paddocks where pooling of water occurs after heavy rainfall. However 2016 results showed that using local knowledge to target sampling to areas to where PRR had been observed gave a slightly better success (4/11 cases) than just targeting low areas of paddocks (3/11 cases) (Table 5). It was notable that in two of the four positive hotspot locations were not in low lying areas of paddocks, rather their location was possibly related to prior the historic presence of alternative hosts in the area of the hotspot. However if prior knowledge of a paddock is not available then it was clear that targeting low lying areas for sampling is an appropriate strategy to maximise the chances of detection. For example, another three paddocks (coded 14, 15 and 16) in wheat in 2015 were low and high area sampled in Goondiwindi in 2016 for which there was no hotspot information, for the single paddock (no. 15) with positive Pm DNA results all three low area samples were positive and no high area samples had positive results.

April vs. Nov. 2016 inoculum results, unexpected increases: Results for four Coonamble paddocks (rainfall June to Oct 2015 of 112 mm, June to Oct 2016 of 388 mm) are presented which included: increases from nil inoculum in a break crop to substantial inoculum in chickpeas including areas with PRR like symptoms (paddocks 1 & 2); increases from nil inoculum in a prior chickpea crop to substantial inoculum in chickpeas including areas with PRR like symptoms in one paddock (paddocks 3 & 5) (Table 6).

All of the Goondiwindi paddocks (rainfall June to Oct 2015 209mm, June to Oct 2016 321mm) with hotspots were in wheat the winter of 2016, but two paddocks (coded 14 and 16) with no hotspots but had low and high area sampled were sown in chickpeas. All April samples for both paddocks had nil Pm DNA values, but in Nov the low sites were positive, for paddock 14 (average Pm DNA 694 copies/g soil) and 16 (average Pm DNA 6174 copies/g soil), and for 16 the high site average value was 8587 copies/g soil. That high sites provided positive values suggests that the inoculum was resident at the samples sites, rather than due to inoculum arriving after April via the flow of storm water containing inoculum. This paddock 16 planted to a PRR susceptible kabuli variety had large areas of PRR in 2016, despite the April presowing nil Pm DNA results from four low and four high sites.

Table 5. April 2016 sample location effects, average Pm DNA (sequences/ g soil) results, number of positive samples, for samples from a single hotspot area, low areas and high areas of paddocks

Paddock code	Av. hotspot P. med DNA	Av. low P. med DNA	Av. high P. med DNA
1	0	0	0
2	0	0	0
3	209^{1*}	418^{1}	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	1389^{3}	1698^{2}	285^{1}
11	690^{2}	0	0
12	2881^{3}	2355^{3}	0

* no. of positive samples, out of three

Table 6. April and November 2016 comparison for four Coonamble paddocks (see paddock codes) April no. of positive Pm DNA samples, Nov average Pm DNA values, Nov no. of positive Pm DNA samples and no. collected (in superscript) for soil samples from a single hotspot area, low areas and high areas of paddocks

		April	April	April
code	2015 crop	Hot no. +	Low no. +	High no. +
1	wh	0/3	0/3	0/3
2	wh	0/3	0/3	0/3
4	cp	0/3	0/3	0/3
6	cp	0/3	0/3	0/3
		Nov.	Nov.	Nov.
code	2016 crop	Hot av.	Low Av.	High Av.
1	cp	0*	$13,110^{3/3}$	$4,107^{1/1}$
2	cp	$1,242^{1/3}$	$6,447^{2/2}$	$2,936^{1/1}$
4	cp	0	$6,662^{3/3}$	$13,248^{2/2}$
6	cp	$3,417^{2/3}$	-#	-#

*only dead seedlings present in hotspot area, possible death from waterlogging, two samples taken from an adjoining area were both Pm positive (av. 19,054 sequences/g soil)

#no disease symptoms observed, no soil samples collected

These results although from a small number of paddocks in a single season (albeit a high rainfall season) were unexpected, as they indicate that results taken prior to the sowing of a crop may not be indicative of future disease and associated inoculum concentrations.

Implications for growers

This work has not been able to develop disease risk categories for Phytophthora root rot of chickpeas using pre-sowing soil inoculum concentrations. There are three main reasons, Pm declines to low levels during break crops within 6-12 months, resting spore concentrations are very low and distribution across paddocks is uneven.

In wet seasons low concentrations of Pm can multiply rapidly to cause PRR. Pm can also spread to neighbouring crops in run-off water.

However the Pm DNA test may be useful as a diagnostic tool for growers and agronomists to confirm PRR diagnosis. For example, in the 2016 some chickpea paddocks in NW NSW were saturated causing some areas of the paddocks die. Pm DNA analysis of soil samples from some of these areas has allowed agronomists and growers to identify if waterlogging or PRR were the cause of the losses.

Where suspected PRR occurs in chickpea crops, confirmation through isolation of the pathogen from diseased tissue can be unsuccessful if the symptoms are advanced or the plants have died. Analysis of soil samples for Pm DNA provided confirmation of a suspected case of PRR in QLD in 2015. The key point to the use of this diagnostic tool will be the need for in-crop soil samples when the pathogen is active and inoculum concentrations are high.

In addition, the Pm DNA test is a valuable research tool as has been used to compare the resistance of breeding lines and varieties to Pm.

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