GRDC Grains Research Update

NORTH STAR

Thursday, 3rd March 2016

Challenge your management decisions!

Grains Research & Development Corporation
Your GRDC working with you

North Star GRDC Grains Research Update

Thursday March 3rd, North Star Sports Club

Agenda

Time	Topic	Speaker (s)
9:00 AM	Welcome	GRDC
9:10 AM	**Field ready frost research for the northern slopes and plains.** Variety management, environmental issues and options.	Tim March (University of Adelaide)
9:40 AM	**High yield cereal and durum agronomy update**.	Rick Graham (NSW DPI)
10:15 AM	**Rust - what worked, what didn't and what's new.**	Steve Simpfendorfer (NSW DPI)
10:35 AM	Morning tea	
11:05 AM	**Managing grain crops in nematode infested fields** to minimise loss and optimise profit.	Richard Daniel (NGA) and Jeremy Whish (CSIRO)
11:40 AM	**How much water does your soil hold? Characterising soils for plant available water capacity (PAWC): methods, tools and accuracy.**	Brett Cocks and Jeremy Whish (CSIRO)
12:10 PM	**Driving and measuring fallow efficiency.**	David Freebairn
12:40 PM	Lunch	
1:40 PM	**Harvest management of canola.**	Maurie Street (GOA) & Rick Graham (NSW DPI)
2:20 PM	**Pulse agronomy** - nutrient omission, time of sowing, varietal interactions, plant population and row spacing.	Bec Raymond (DAF Qld)
2:55 PM	**Chickpea diseases** – critical issues to focus on in 2016.	Kevin Moore (NSW DPI)
3:15 PM	Close	

Contents

RANKING CEREAL VARIETIES FOR FROST SUSCEPTIBILITY USING FROST VALUES.. 4
Tim March, Michael Laws, Paul Eckermann, Paul McGowan, Simon Diffey, Brian Cullis, Richard Maccallum, Brenton Leske, Ben Biddulph, Jason Eglinton

HIGH YIELD CEREAL AND DURUM AGRONOMY UPDATE 9
Rick Graham

WHEAT RUST IN 2015 – WHERE ARE WE HEADING?... 10
Steven Simpfendorfer

IMPACT FROM *PRATYLENCHUS THORNEI,* MACALISTER 2015.. 16
Brendan Burton and Linda Bailey, Northern Grower Alliance Kedar Adhikari

ROOT-LESION NEMATODES (*PRATYLENCHUS THORNEI*): HOW LONG DOES IT TAKE TO REDUCE THEIR POPULATION WITHIN THE SOIL? 26
Jeremy Whish and John Thompson

DRIVERS OF FALLOW EFFICIENCY: EFFECT OF SOIL PROPERTIES AND RAINFALL PATTERNS ON EVAPORATION AND THE EFFECTIVENESS OF STUBBLE COVER.. 34
Kirsten Verburg, Jeremy Whish

METHODS AND TOOLS TO CHARACTERISE SOILS FOR PLANT AVAILABLE WATER CAPACITY........................ 39
Kirsten Verburg, Brett Cocks, Tony Webster, Jeremy Whish

SOILWATERAPP – A NEW TOOL TO MEASURE AND MONITOR SOIL WATER.. 52
David Freebairn

IMPROVING FALLOW EFFICIENCY 55
David Freebairn

COMMONLY ASKED QUESTIONS ABOUT SOIL WATER AND SOIL MANAGEMENT 59
Graeme Wockner and David Freebairn

"TO WINDROW OR NOT TO WINDROW IN 2016?" THIS IS THE QUESTION, "BUT IF SO, WHEN?" 65
Maurie Street

CANOLA HARVEST MANAGEMENT IN NORTHERN NSW – SNAPSHOT OF RESULTS FROM YEAR 1 78
Leigh Jenkins, Rick Graham, Rohan Brill, Rod Bambach and Don McCaffery

FABA BEAN AGRONOMY – IDEAL ROW SPACING AND TIME OF SOWING 83
Rebecca Raymond, Kerry McKenzie, RCN Rachaputi

NORTHERN NSW PULSE AGRONOMY PROJECT –NUTRITION IN CHICKPEA 2015 91
Andrew Verrell and Leigh Jenkins

NORTHERN WINTER PULSE AGRONOMY - FABA BEAN DENSITY EXPERIMENTS - 2015 93
Andrew Verrell and Leigh Jenkins

PBA NASMA FABA BEAN – EFFECT OF SEED SIZE AT SOWING ON GRAIN YIELD... 96
Andrew Verrell and Leigh Jenkins

INTEGRATED MANAGEMENT OF CROWN ROT IN A CHICKPEA – WHEAT SEQUENCE 99
Andrew Verrell

CHICKPEAS – WHAT WE LEARNT IN 2015 AND RECOMMENDATIONS FOR 2016 103
Kevin Moore, Leigh Jenkins, Paul Nash, Gail Chiplin and Sean Bithell

CHICKPEA ON CHICKPEA – IS IT WORTH IT? 108
Kevin Moore, Kristy Hobson and Sean Bithell

CHICKPEA ASCOCHYTA – LATEST RESEARCH ON VARIABILITY AND IMPLICATIONS FOR MANAGEMENT 111
Kevin Moore, Kristy Hobson, Nicole Dron, Prabhakaran Sambasivam, Rebecca Ford, Steve Harden, Yasir Mehmood, Jenny Davidson, Shimna Sudheesh, Sukhjiwan Kaur and Sean Bithell

EFFECT OF CHICKPEA ASCOCHYTA ON YIELD OF CURRENT VARIETIES AND ADVANCED BREEDING LINES – THE 2015 TAMWORTH TRIAL VMP15...117
Kevin Moore, Kristy Hobson, Steve Harden, Paul Nash, Gail Chiplin and Sean Bithell

PHYTOPHTHORA IN CHICKPEA VARIETIES HER15 TRIAL –RESISTANCE AND YIELD LOSS..............................122
Kevin Moore, Lisa Kelly, Kristy Hobson, Steve Harden, Willy Martin, Kris King, Gail Chiplin and Sean Bithell

A NEW DNA TOOL TO DETERMINE RISK OF CHICKPEA PHYTOPHTHORA ROOT ROT 125
Sean Bithell, Kevin Moore, Kristy Hobson, Steve Harden, Willy Martin and Alan McKay

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

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

Ranking cereal varieties for frost susceptibility using frost values

Tim March[1], Michael Laws[1], Paul Eckermann[1], Paul McGowan[2], Simon Diffey[3], Brian Cullis[4], Richard Maccallum[5], Brenton Leske[6], Ben Biddulph[6], Jason Eglinton[1]

[1] School of Agriculture, Food & Wine, The University of Adelaide
[2] Innovative Food Technologies, Agri-Science Queensland, Department of Agriculture and Fisheries
[3] Statistics for the Australian Grains Industry (SAGI), Centre for Crop and Disease Management, Curtin University
[4] Statistics for the Australian Grains Industry (SAGI), National Institute for Applied Statistics Research Australia (NIASRA), University of Wollongong
[5] NSW Department of Primary Industries
[6] Department of Agriculture and Food Western Australia

Keywords

Frost, wheat, barley, grain sterility, frost induced sterility, flowering

GRDC project code

UA00136, DAW00234, UW00005

Take home message

- Wheat and barley varieties differ in susceptibility to reproductive frost damage during booting and flowering.
- Barley is less susceptible to reproductive frost damage than wheat. No varieties are frost tolerant. Under severe frost (for example -8°C) or multiple minor frosts (several nights of -2° to -4°C) all varieties tested to date are equally susceptible, resulting in up to 100 percent sterility in flowering heads.
- Variation in reproductive frost susceptibility has not been linked to variation in susceptibility to stem frosts experienced in 2014 across Southern Australia or to later frosts during grain filling.
- Frost Values have been developed for cereal varieties to rank their relative susceptibility to reproductive frost. This information will be available through the use of an interactive tool on the National Variety Trial website and can be used to manage frost risk and fine tune variety selection after first selecting for local adaptation, yield, flowering time, and other key target traits.

Background

Frost has been estimated to cost Australian growers around $360 million in direct and indirect yield losses every year.

Breeding new cereal varieties with improved frost tolerance is one solution to minimise financial losses due to frost. Historically little has been known about variation for frost tolerance in Australian varieties, leading to the assumption that little variation exists. The limited knowledge about frost tolerance is also due to the practical difficulties in measuring frost damage under field conditions due to the sporadic and dynamic nature of frost events. However, successive GRDC funded projects have enabled dedicated frost screening nurseries to be developed in SA, WA and NSW. These nurseries have enabled the measurement of susceptibility to reproductive frost under minor frosts with greater accuracy and repeatability than previously. This research is part of the GRDC's multidisciplinary National Frost Initiative.

Methodology

The frost susceptibility data is generated from research trials grown in frost prone parts of the commercial production environment near Loxton SA, Merredin and Wickepin WA and Narrabri NSW in 2012, 2013 and 2014. To improve the predictions for these environments, similar trials grown in Loxton SA in 2010 and 2011 were also included in the analysis.

At each site, between 6 and 11 times of sowing (TOS) are planted as separate blocks at approximate equidistant thermal time from around April 15 to June 15 at each site to increase the probability that the test lines are at the flowering stage when a natural frost event occurs. On site weather stations monitor the temperature at the crop canopy. Following a frost event, 30 flowering heads are tagged and then assessed for frost induced sterility (FIS) during grain fill 4-6 weeks later. FIS is assessed on the outside grains of every spikelet excluding the terminal and basal spikelets. This approach minimises confounding effects due to maturity and enables repeatable results over successive seasons and sites. Different research agencies conducted the trials in each state, although the same protocols were used. Table 1 gives a summary of the trials.

The genotypes that were grown included a selection of the most commonly grown wheat and barley varieties in the three states, genotypes which had been well characterised previously for frost tolerance and other genotypes of particular interest to breeding companies.

Table 1. Summary of wheat experiments used in analysis, replications =2.

State	**Location**	**Year**	**Number of Sowing dates**	**Number of Varieties**
SA	Loxton	2010	6	35
		2011	6	36
		2012	11	65
		2013	10	65
		2014	10	72
WA	Merredin	2012	7	48
	Wickepin	2013	6	54
	Wickepin	2014	8	72
NSW	Narrabri	2012	7	30
		2013	7	32
		2014	7	32

Results and discussion

When cereal varieties are flowering on the same day and a frost occurs, there is a wide range in frost susceptibility within commercial varieties under mild reproductive frost conditions (minimum temperature -1° to -3°C) (Figure 1). Under very severe frost (for example -8°C) or multiple minor frosts (several nights of -2° to -4°C) all varieties are equally susceptible, resulting in up to 100 per cent sterility. It should be noted that the relationship between canopy temperature and FIS is complex and can be confounded by TOS, variety and environmental factors. Understanding this relationship will be the focus of ongoing research.

Frost values

The relative ranking of the frost susceptibility has been expressed as a frost value (FV) for each variety in each environment. FVs are presented as positive or negative differences relative to the average frost induced sterility (FIS) of all varieties in the current data-set for a given year and site. Low FVs are more desirable than high FVs. The units of measurement for FVs relate to the transformed FIS data and therefore do not directly correspond to a particular level of frost damage. Therefore the comparative ranking between a subset of varieties of interested should be considered when making variety decisions as it is the difference between FVs that is critical.

When using FVs for selection decisions, it is recommended that growers and advisors consider not just a single environment/year, but a number of relevant environments. This allows examination of stability of variety performance over a range of environments which are prone to frosts.

FVs can be displayed graphically for a set of either wheat or barley varieties of interest using the interactive tool that is available from NVT Online (http://www.nvtonline.com.au/) an example of this is shown in Figure 2.

The rankings are currently based on the variation in wheat and barley variety's ability to maintain grain number under minor reproductive frosts. Under reproductive/floret or head frosts, grain number is the main yield component affected. Yield is a function of grain size multiplied by grain number and hence grain number normally corresponds to yield. However, this may not be the case if there is variation in the length of season and the ability of varieties to compensate with late tillers, synchronisation of flowering time or plasticity of grain number. Therefore, it is critical that varieties are selected on local adaptation and yield first and FVs are only used to identify and manage frost risk.

Further research is ongoing to validate the yield relationship with FIS (DAW00234) and also compensation ability (CSP00180) as part of the GRDC's multidisciplinary National Frost Initiative.

In addition it is important to note that research to date has not conclusively assessed if the variation in reproductive frost susceptibility is related to susceptibility to frost during stem elongation and grain filling.

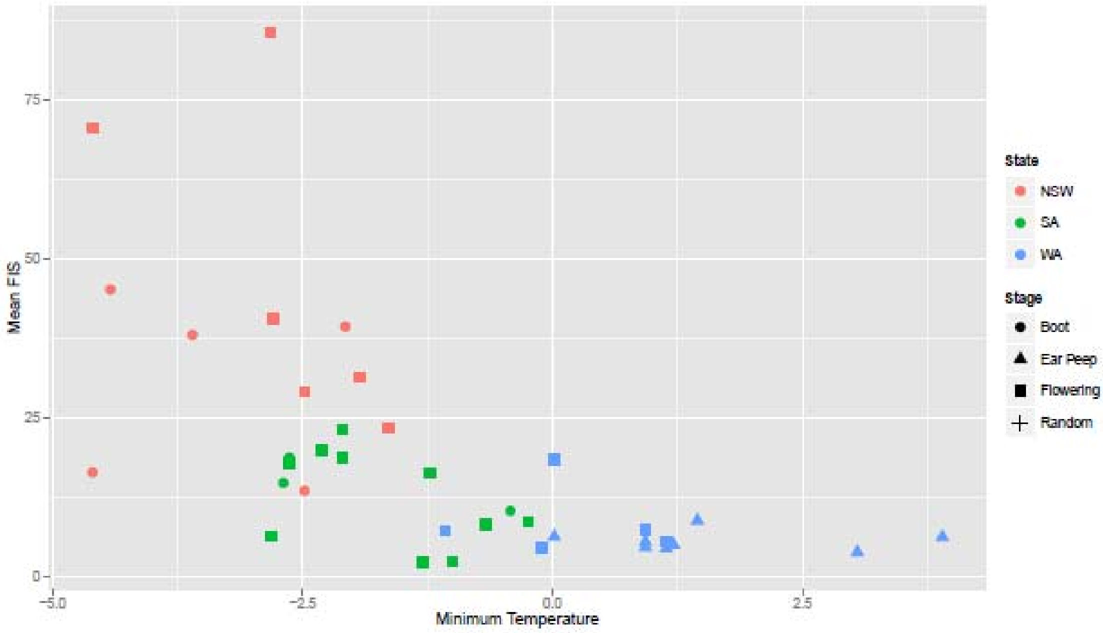


Figure 1. Relationship between minimum temperature in 3 environments and raw FIS data for each wheat tagging event, at different development stages in 2012-2013.

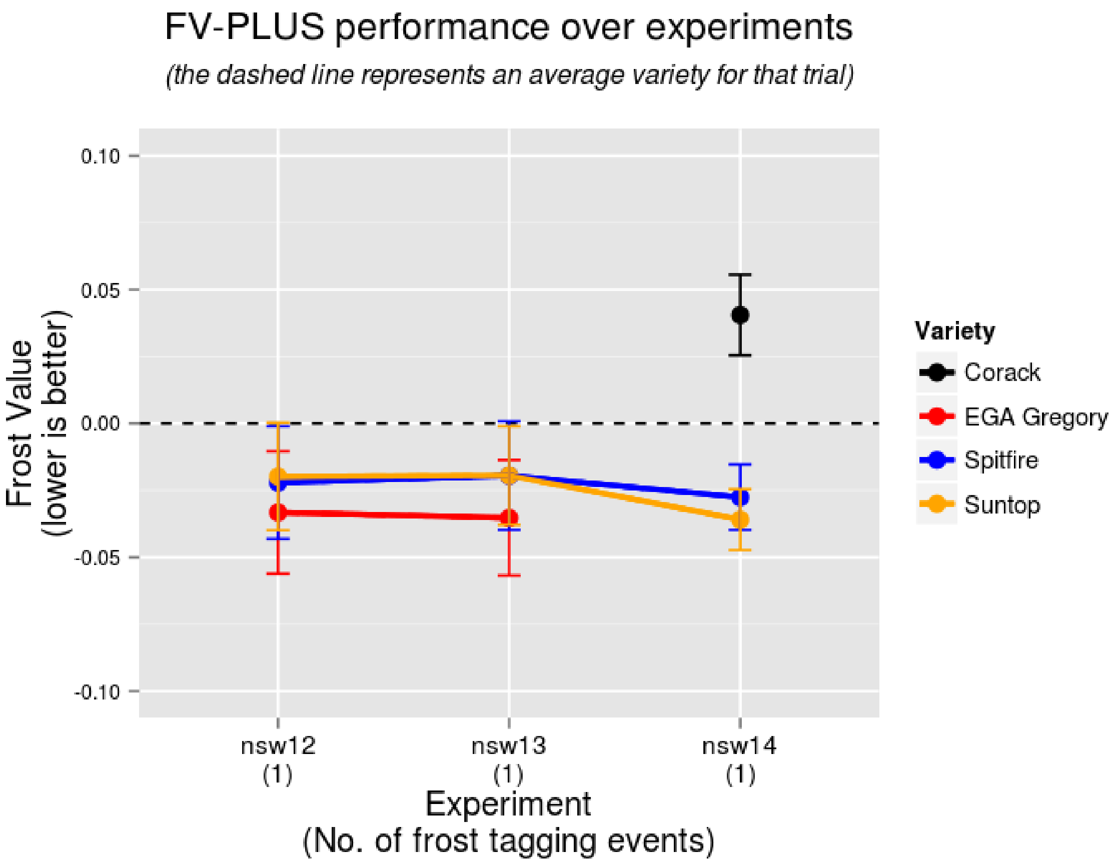


Figure 2. Frost Value graph for five wheat varieties tested at Narrabri NSW. Each FV for each variety is presented along with prediction standard error bars. The number of tagging events is indicated in brackets for each site/year. Lower FVs are better.
(ⓓ EGA Gregory, Spitfire, Suntop & Corack are all varieties protected under the Plant Breeders Rights Act 1994)

Conclusion

As frost exerts a complex production constraint in cropping systems, it requires a package of risk management strategies. These strategies should include pre-season, in-crop and post frost management tactics. These tactics should be regularly reviewed and updated as part of annual farm management planning and as new ideas and research findings are uncovered.

Variation in cereal varieties for reproductive frost susceptibility is just one component of a management strategy and may be used to fine-tune variety selection to manage the risk of frost damage.

Acknowledgements

The authors acknowledge Mr Nathan Height and Mike Baker DAFWA for Technical support. Trials in Narrabri were sown and managed by Kalyx and by Living Farm in Wickepin. This research was funded by the GRDC and is part of the National Frost Initiative.

Contact details

Richard Maccallum
NSW Department of Primary Industries
Ph: 02 6895 1025
Email: richard.maccallum@dpi.nsw.gov.au

Tim March
University of Adelaide
Ph: 08 8313 6700
Email: tim.march@adelaide.edu.au

Jason Eglinton
University of Adelaide
Ph: 08 8303 6553
Email: jason.eglinton@adelaide.edu.au

Ben Biddulph
DAFWA, South Perth
Ph: 08 9368 3431
Email: ben.biddulph@agric.wa.gov.au

High yield cereal and durum agronomy update

Rick Graham, NSW DPI

Contact details

Rick Graham
NSW DPI
Mb: 0428 264 971
Email: ricky.graham@dpi.nsw.gov.au

Wheat rust in 2015 – where are we heading?

Steven Simpfendorfer, NSW DPI

Key words

Stripe rust, management, variety purity, leaf rust, disease standards, Adult Plant Resistance (APR)

GRDC code

DAN00176: Northern NSW integrated disease management

Take home message

- Stripe rust has not gone away!
- Know the difference between a ‘hot individual plant’ and a ‘hot-spot’ before creating panic
- If you had stripe rust in your EGA Gregoryᶲ in 2015 it is likely a seed purity issue. Consider freshening up your seed source.
- EGA Gregoryᶲ remains MR to stripe rust and does NOT require fungicide application
- Consider ‘up-front’ or early season fungicide management of stripe rust in Suntopᶲ in 2016, especially under higher nitrogen status
- Be aware of the development and spread of new wheat leaf rust pathotypes in your region
- The north is on track with rust management, do not slip on minimum disease standards, any perceived short-term gains are likely to result in long-term pain for ALL.

Stripe rust in 2015

Stripe rust first appeared in wheat crops in north NSW/southern Qld (North Star and Goondiwindi) in moderately susceptible (MS) varieties (Sunzellᶲ and Gauntletᶲ) at the start of August in 2015. Cooler autumn/winter temperatures and rainfall during this period were very conducive to the development of stripe rust in 2015. Stripe rust infection occurs as long as there is leaf wetness of between for 5-6 hours (minimum 3 h) with temperatures below 20^{o}C (optimum 6^{o}C to 12^{o}C). During much of the growing season these conditions usually occur overnight. There were numerous reports of stripe rust ‘hot-spots’ in the MR-MS variety Suntopᶲ across regions in 2015. Samples of stripe rust were submitted to the Australian Cereal Rust Control Program (ACRCP) at the University of Sydney’s Plant Breeding Institute throughout the 2015 season, with pathotypes 134 E16 A+ (WA pathotype), 134 E16 A+ 17+ (WA Yr 17+ pathotype) and 134 E16 A+ 17+ 27+ (WA Yr 17+27+ pathotype) confirmed in Queensland and northern NSW.

Three non-fungicide treated GRDC funded NVT trials were conducted in northern NSW (North Star, Spring Ridge and Tamworth) in 2015. Early and very high levels of stripe rust developed in the North Star and Tamworth sites with lower and later development of stripe rust occurring at the Spring Ridge site. All trials allowed good evaluation of the relative resistance of wheat varieties and advanced breeding lines to stripe rust in the absence of fungicide protection.

All sites were exposed to natural infection from stripe rust. That is, they were not artificially inoculated with stripe rust spores. The development of significant levels of stripe rust at all three geographically spread sites highlights that stripe rust inoculum was not a limiting factor in the 2015 season. All rusts (stripe, leaf and stem) are ***biotrophs*** which means they require a living host to survive between seasons. This is primarily volunteer wheat in the case of cereal rusts but wheat stripe rust has been shown to also survive on barley grass in some seasons. Barley grass also gets infected by a barley grass specific stripe rust pathogen that cannot infect wheat but can cause infection on some barley varieties. Barley stripe rust is not currently present in Australia which is fortunate, as overseas screening indicates that around 80% of current barley varieties would be MS or worse if this exotic pathogen was to establish here (William Cuddy, personal communication). Any samples of stripe rust on barley or barley grass should be submitted to the ACRCP for pathotype determination. The higher probability of summer rainfall in northern NSW/Qld is conducive to the survival of volunteer wheat between cropping seasons which is commonly referred to as the ***green bridge***. When combined with a wide spread in sowing times of roughly between March for dual purpose wheat varieties through to June for quicker maturing main season varieties this situation is quite conducive to the survival and development of stripe rust.

Early and severe infection levels developed at the North Star site with the WA Yr17+27+ confirmed as the dominant pathotype in the trial. The WA Yr17+ pathotype developed as a mutation of the original WA pathotype, being first detected in 2006. This pathotype further mutated to develop virulence for the *Yr27* gene with the WA Yr17+27+ pathotype first detected in 2011, which reduced the resistance level of varieties such as Livingstonᶲ and Merindaᶲ (Figure 1). All three pathotypes are now distributed across the northern region including into Qld.

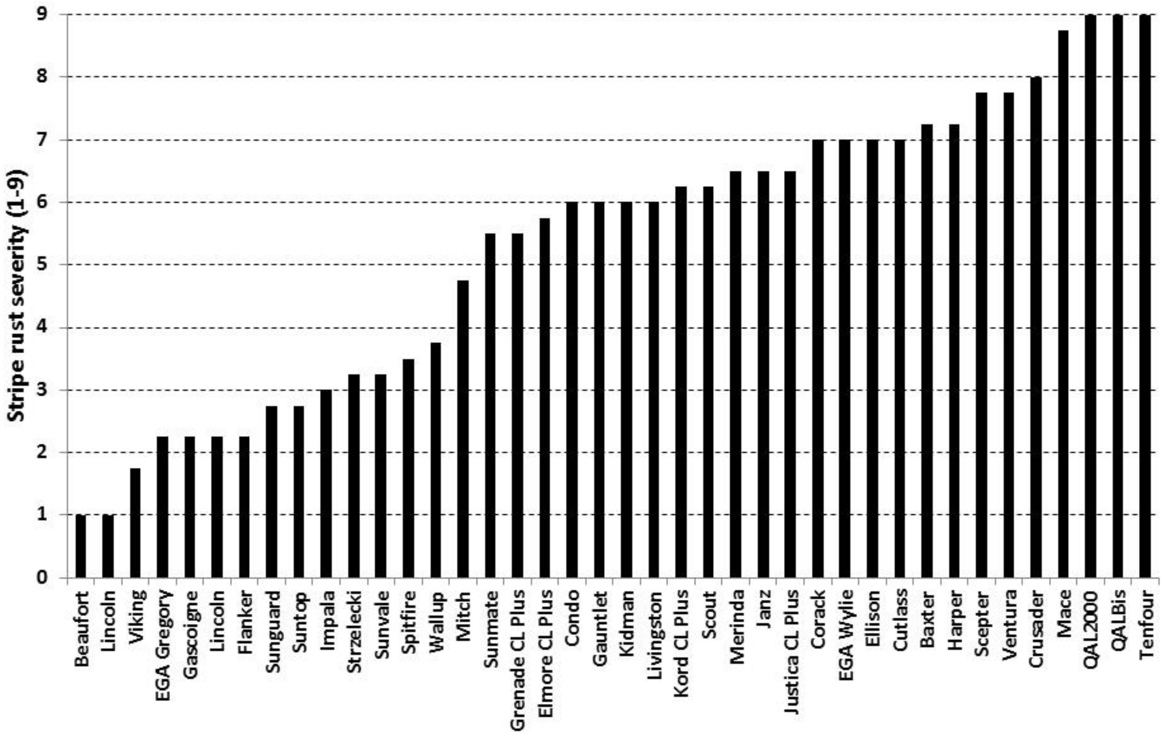


Figure 1. Stripe rust reaction of released wheat varieties in main season NVT - North Star 2015 (Note trial site had early and high stripe rust pressure in 2015 from the WA 17+27+ pathotype. Scores are on the ACRCP 1-9 scale where 1 = no pustules evident and 9 = whole leaf covered in pustules. Individual site data is presented above and **not** an overall variety rating which is derived from reactions in multiple trials across regions and seasons)

Stripe rust in EGA Gregoryᶲ

Two reports of the supposed 'break down' of stripe rust resistance in EGA Gregoryᶲ occurred around Wongarbon and Warialda in 2015. NSW DPI inspected the EGA Gregoryᶲ crop at Wongarbon and there were 'hot individual plants' NOT 'hot-spots' evident in the crop. A 'hot-spot' is **all** plants in at least a 1 m circle with development of pustules and occurs due to higher humidity during winter causing spores to remain in small clumps that are relatively heavy, which limits spread by wind. Spread is therefore mostly over small distances, which results in the appearance of 'hot-spots' of infection usually first appearing in late winter to early spring. All plants along multiple 1 m sections of row affected by stripe rust were pulled from the EGA Gregory⦶ crop at Wongarbon and separated into individual plants. It then became obvious that there were individual plants along the row infected with stripe rust and others with no visible signs of infection. That is, there were infected individual plants ('hot individual plants') but **not** every plant along a 1 m section of row and adjoining rows infected with stripe rust. There were **no** 'hot-spots' evident in the paddock. This process was explained and repeated by the consulting agronomist with the Warialda EGA Gregory⦶ crop who similarly concluded that it was 'hot individual plants' and clearly not 'hot-spots'. To complete the picture, individual heads from visually infected and uninfected plants from Wongarbon were collected and sent to the University of Southern Queensland (USQ) for molecular analysis to determine varietal purity. Grain collected from 6 out of 6 plants without visible stripe rust infection were identified as EGA Gregory⦶. In contrast seed collected from 5 of 8 plants with stripe rust infection were identified as NOT being EGA Gregory⦶ but all had a similar banding pattern indicating they were all the one contaminant. The actual contaminant variety was not determined but clearly it has increased susceptibility to stripe rust. In both situations the concern around stripe rust appears to be related to more susceptible off-types (contaminants) in the EGA Gregory⦶ crops. Pure EGA Gregory⦶ remains MR to stripe rust and does not require fungicide management. MR varieties such as EGA Gregory⦶ can still develop low levels of stripe rust under high pressure as was evident at North Star in 2015 (Figure 1). However, the level of infection, while visible, does not result in the loss of enough green leaf area to cause significant economic yield loss. If growers are concerned about the levels of stripe rust in their EGA Gregory⦶ then they should consider freshening up their seed source to one with a known and higher purity.

Stripe rust 'hot-spots' in Suntop⦶

'Hot-spots' of stripe rust occurred in two crops around Wellington in 2013, several crops across eastern Australia in 2014 and in numerous crops of Suntop⦶ in eastern Australia in 2015. 'Hot-spots' of stripe rust first appeared in Suntop⦶ crops in northern NSW in early-mid August in 2015. 'Hot-spots' in Suntop⦶ across seasons has been generally linked with higher nitrogen status within paddocks with some paddocks only developing 'hot-spots' in the headlands where double the N rate was applied at sowing. Generally, affected Suntop⦶ crops had no up-front fungicide management and did not have a fungicide application around GS30, which commonly occurs commercially in combination with an in-crop herbicide. There is no new pathotype of stripe rust with increased virulence to Suntop⦶ and it has been confirmed from different paddocks that there is currently no underlying issue with seed purity. That is, crops are pure Suntop⦶ and furthermore true 'hot-spots' are evident in affected paddocks and **not** isolated individually infected scattered plants which would be more indicative of an issue with seed purity.

Suntop⦶ is rated MR-MS to stripe rust, which indicates that it requires one fungicide input (up-front or early between GS30-32) to limit disease development. This message can become complicated as it is often tweaked to the likely timing of epidemic development (significant green-bridge over summer likely to favour earlier epidemic), conduciveness of environment (west of Newell Highway generally drier and hotter which reduces disease pressure) and sowing time (earlier sowing likely to be more favourable to stripe rust and early epidemic development). Generally, varieties such as Suntop⦶ (MR-MS), Lancer⦶ (MR) and even EGA Gregory⦶ (MR) rely largely on Adult Plant Resistance (APR) genes that slow down the rate of disease development. In general, the resistance of the plant increases with plant age and as the temperature rises. The APR gene in EGA Gregory⦶ (*Yr18*) generally appears to express earlier than the gene (*Yr31*) in Suntop⦶. APR in Suntop⦶ appears to be more interactive with lower temperatures and higher N levels which both appear to delay the expression of APR within the leaves. The timing of APR expression remains one of the major issues with stripe rust management in the northern grains region which differs with variety, sowing time, temperature and even N status. When 'hot-spots' occurred in many Suntop⦶ crops in 2015 the actual infection became more obvious because APR had expressed and killed off infected cells within the leaf and the surrounding cells. This renders the infection non-viable by denying the stripe rust fungus of living cells to survive in. Yellow flecking of the flag leaf and other leaves on uninfected Suntopᶲ plants adjacent to the 'hot-spots' indicated the active expression of APR killing spores landing and trying to infect these plants. A close inspection of the oldest leaves (seedling leaves) within the 'hot-spots' revealed a mass of old discoloured pustules which highlights that the infection had been present in these patches for a considerable period. Suntopᶲ still has a very useful level of resistance to stripe rust and is by no means a 'sucker' for stripe rust. This fact is often not easily acknowledged at the grower level when Suntopᶲ for example, may be the most susceptible variety they are currently growing. Hence, the appearance of any infection and the estimation of yield loss (loss of green leaf area) can appear exaggerated without a true susceptible variety to compare infection levels with (Figure 1). Personally, the infection levels observed in 'hot-spots' of Suntopᶲ in 2015 were consistent with an MR-MS reaction. Varieties such as Suntopᶲ which rely on APR as their main source of resistance are worthwhile protecting at early growth stages with seed or fertiliser treatments or an in-crop fungicide application around GS30-32. This will provide protection until APR is expressed later in the season.

Stripe rust management in 2016

The key messages remain the same;

- control the green bridge (volunteer wheat) at least four weeks prior to sowing to delay the onset of epidemics
- select varieties with improved levels of resistance (MR-MS minimum)
- ensure variety identification/purity
- tailoring fungicide strategies to varietal resistance level, rainfall zone, growth stage and seasonal conditions
- monitor crops regularly.

With varieties such as Suntopᶲ that rely largely on APR, consider using an in-furrow fungicide to protect early growth. Flutriafol on starter fertiliser has been shown to provide extended protection against stripe rust in the northern region and is a more common component of stripe rust management strategies for susceptible wheat varieties in the southern region. Fluquinconazole seed treatment also protects early growth but tends to not provide the same length of protection as in-furrow treatments in northern trials.

Be 'alert not alarmed' of leaf rust pathotypes

There are two new pathotypes of leaf rust of potential significance to northern NSW and Qld. The first (76-3,5,7,9,10,12,13 +Lr37) was a mutation of an existing pathotype with combined virulence for the genes *Lr13*, *Lr24* and *Lr37*. It was first detected around Warialda on the feed wheat variety Naparooᶲ in 2013 and has only really caused issues in this variety in subsequent seasons. A newer 'SA pathotype' of leaf rust (104-1,3,4,6,7,8,10,12 +Lr37) is an exotic introduction to Australia and was first detected in South Australia in 2014. The SA pathotype of leaf rust has rapidly spread north being detected at Dunedoo, Tamworth, North Star and Gatton in 2015 but not at levels that warranted fungicide application. However, this is a warning for subsequent years and growers should check the rating of varieties to these new leaf rust pathotypes with a minimum disease standard of MS recommended by the ACRCP for the northern region. Impalaᶲ, which has a leaf rust rating of S to existing leaf rust pathotypes, has required fungicide management in northern NSW in recent seasons when conditions (humid and temperatures between 15°C to 25°C) have been conducive to disease development.

Avoid growing susceptible varieties – has the message changed?

No!

The northern region did the right thing by moving away from growing very susceptible varieties such as H45⫯. Numerous field trials across the northern region, largely GRDC funded NVT trials where stripe rust development is routinely controlled with a fungicide management program, highlight that there is no yield penalty associated with growing newer varieties with improved levels of stripe rust resistance. There is a big difference in the level of fungicide intervention required across a season with a susceptible variety (likely three fungicide inputs) compared to an MR-MS variety (one fungicide 'up-front' or around GS30-32) to manage stripe rust in the northern region.

Why are minimum disease standards important?

Minimum disease standards of MR-MS for stripe and stem rust and MS for leaf rust are recommended by the Consultative Committee of the ACRCP for wheat varieties in the northern region (Qld and nth NSW). Selecting varieties with these minimum levels of resistance reduce the build-up of rust epidemics within the region (the more susceptible the variety the bigger issue they are as a green bridge), decrease disease pressure from existing rust pathotypes within the season, reduce the probability of mutations within existing pathotypes occurring with increased virulence to existing rust-resistance genes and reduces the reliance on fungicides as a management tool. The continued production of susceptible and very susceptible varieties, while stripe rust can be controlled with fungicides, jeopardises current and future disease resistance genes. The problem is if you choose to go this way and become reliant on the continuous use of fungicides in susceptible varieties then you are potentially making that decision for the whole industry as rust spores can be spread large distances by wind. Mutations that develop on your farm rapidly spread across regions.

Is fungicide resistance an issue?

A mini-review was recently written on the risk of rust fungi developing resistance to fungicides (Oliver 2014). To summarise, the rust fungi are classified as having a low risk of developing fungicide resistance, which appears justified by long fungicide usage patterns mainly overseas with no confirmed cases of agronomically significant fungicide resistance being reported in a rust pathogen species. The general conclusions from the review were 'Rust fungi have a reputation that suggests they are immune to the development of fungicide resistance, and this has led growers to rely heavily on fungicides for the control of diseases such as stripe rust. This reputation is based on a long history, during which many other species have developed often disastrous resistance to fungicides, especially *Botrytis, Zymoseptoria* and powdery mildews, while rusts have remained well controlled". Within Australia, barley powdery mildew in WA and *Septoria tritici* blotch (*Zymoseptoria,* STB) of wheat in the southern region have been reported in recent years to have developed partial resistance to triazoles. In terms of cereal rusts, the strobilurins (Group 11) are 'protected by a serendipitous intron, DMI fungicides (triazoles, Group 3) are protected by relatively low resistance factors and SDHIs (Group 7; medium to high risk of resistance development) have been protected by mixing with other fungicides and their recent introduction". However, the reviewer still urges vigilance when it comes to the rusts.

It is interesting that in the review (Oliver 2014) the argument that rust fungi are regularly exposed to fungicides but have not yet developed any resistance was largely based on more extended use patterns overseas. "In Europe, where fungicide use on wheat is close to universal, rusts have been regularly exposed to fungicides, even though other species, such as *Blumeria graminis* (powdery mildew) and *Zymoseptoria tritici* (STB), are the prime targets'. It is therefore not too hard to imagine that the converse could occur in Australia where reliance on controlling stripe rust in susceptible wheat varieties is the main target for repeat fungicide applications but this practice is potentially selecting for resistance in other fungal species such as powdery mildew and STB that have a medium to high risk for developing fungicide resistance. Fungicide development and the search for new chemistries in Europe are continually driven by the evolution of resistance within STB to existing and recently released fungicides. This is **NOT** a good scenario and as an industry we would be wise to learn from their mistakes!

Acknowledgements

The research undertaken as part of project DAN00176 is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. The project is co-funded by the NSW state government through the NSW DPI who are also thanked for their support in fully funding my position and laboratory and other infrastructure costs. Information on changes in cereal pathotypes and distribution are developed through annual surveys conducted by the Australian Cereal Rust Program which is led by the University of Sydney with funding from GRDC and NSW DPI. Molecular analysis of varietal purity of EGA Gregory seed collected from the crop near Wongarbon was kindly conducted by Dr Anke Martin at the University of Southern Queensland. Stripe rust variety evaluations were conducted under the GRDC funded NVT system with trials in NSW co-ordinated by Dr Andrew Milgate (NSW DPI, Wagga Wagga).

References

Oliver RP (2014) A reassessment of the risk of rust fungi developing resistance to fungicides. *Pest Management Science*, 70: 1641-1645.

Further information

http://rustbust.com.au/

Reviewed by

Professor Robert Park, Dr William Cuddy and Dr Guy McMullen

Contact details

Steven Simpfendorfer
NSW DPI
Ph: 0439 581 672
Email: steven.simpfendorfer@dpi.nsw.gov.au

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

Impact from *Pratylenchus thornei,* Macalister 2015

Brendan Burton and Linda Bailey, Northern Grower Alliance
Kedar Adhikari, Sydney University Narrabri

Key words

Pratylenchus thornei, yield, tolerance, wheat

GRDC code

NGA00004: GRDC Grower Solutions for Northern NSW and Southern Qld

Take home message

1. Multi-crop and variety trials were conducted over strips of 'medium' and 'high' *Pratylenchus thornei* (*Pt*) pressure.
2. Site characterised by generally high crop yields (cereals~4-5.5t/ha, chickpeas ~3.5-4.0t/ha) combined with lower levels of *Pt* yield impact.
3. Negligible decline in *Pt* population during the 21 month fallow leading up to the winter trials being planted.
4. No evidence of yield impact from *Pt* in the brassica, faba bean, chickpea and barley trials.
5. Greater yield loss observed in the wheat trials compared to the barley and broadleaf crops at this site.
6. Addition of crown rot inoculum together with 'high' *Pt* pressure significantly increased mean yield loss (~30%) over a set of six wheat varieties compared to either the effect from crown rot inoculum alone (~13%) or *Pt* alone (~8%).

Background

Previous work has highlighted that the root-lesion nematode, *Pratylenchus thornei (Pt),* is one of the key 'diseases' for winter cereal production in the northern grains region. *Pt* is a major constraint due to: the large impact on yield and economics when intolerant wheat varieties are grown, broad geographic distribution with *Pt* populations frequently at high levels and the susceptibility (*Pt* hosting ability) of key rotation crops such as chickpeas and faba beans.

Successful *Pt* management will involve a range of practices including on-farm hygiene and soil testing to identify problem paddocks. However crop and variety choice are still the major tools used for management. Wheat varieties are well characterised in terms of *tolerance* (yield impact suffered during the year of crop production) and *resistance* (impact from variety on the multiplication or build-up of *Pt*). Both characteristics are important for long term management.

This paper reports on trial work conducted between 2013 and 2015 at a site located near Macalister, approximately 40km north-west of Dalby, Qld. The activity was designed to improve our understanding of the differences in tolerance between a range of winter crops and varieties followed by an assessment of the impact of these options on subsequent *Pt* densities. An approach was used to create alternating strips of differing *Pt* population where the impact of increased *Pt* numbers on each variety could be evaluated. While our intentions from a trial point of view were to create strips of 'low' and 'high' *Pt* populations, in actual fact we ended up with strips of 'medium' and 'high' *Pt* population based on the Predicta B® risk category rating. For this reason, the strips will be referred to as medium (or 'med') and 'high' for the remainder of the paper.

Primary aims

1. Evaluate the impact from *Pratylenchus thornei* (*Pt)* on the **yield and economic returns** from a range of winter crops and varieties
2. Examine the impact from different winter crops and varieties on the **multiplication of *Pt***

Trial activity 2013

Soil testing was conducted in a paddock that had grown chickpeas in 2012. Initial samples were taken at 0-30cm on the 4th April 2013, and analysed by the PreDicta B method revealing an initial population of ~6 *Pt*/g soil. The site also appeared suitable due to a suspected low level of crown rot given only one wheat crop had been grown in the paddock over the past ten years. In addition, negligible levels of other common plant-parasitic nematodes (*Merlinius brevidens)* were found and *Pratylenchus neglectus* were not detected.

The aim in 2013 was to create 'strips' of alternating *Pt* population to allow multi-crop evaluation in 2014. Commercial strips, 18m wide, of Strzelecki wheat or Caparoi durum were planted on the 11th June 2013. Strzelecki was used to maximise the increase in *Pt* population and Caparoi durum was selected as an option that limits multiplication. Strzelecki is rated as S-VS (susceptible to very susceptible) and Caparoi is rated as R-MR (resistant to moderately resistant) for *Pt* resistance - or multiplication.

The first significant rainfall event at the trial site following the 2013 harvest was in March 2014 when approx. 150mm rainfall was received. Unfortunately, this rainfall was not sufficient to enable the trial program to be initiated for winter 2014.

The first soil sampling opportunity for *Pt* following harvest of the wheat strips was conducted on the 13th June 2014 once the topsoil had sufficiently dried following the March rain. This sampling provided a first measure of the population differences between the alternating strips. The extended dry period continued into the spring of 2014, and consequently the summer trials planned for 2014 were also deferred.

Further soil sampling was conducted on the 18th February 2015 leading into the 2015 winter season. Soil moisture conditions in autumn 2015 allowed the planting of all the winter season trials. Another round of *Pt* sampling was carried out on the 12th August 2015 to confirm *Pt* population size prior to the summer crop plantings.

Variety and fallow Impact on Pt populations

Figure 1 shows the comparison of *Pt*/g soil (at a depth of 0-30cm) in the strips where Strzelecki and Caparoi durum had been grown in 2013 together with the initial site result. Strips sown to Strzelecki in 2013 had significantly higher *Pt* populations than where Caparoi had been sown at all three sampling times. At both sampling times in 2015, there was still approx. a 7-10 fold difference in *Pt* population between the strips with levels of ~3-4 *Pt*/g soil following Caparoi and ~29 *Pt*/g soil following Strzelecki.

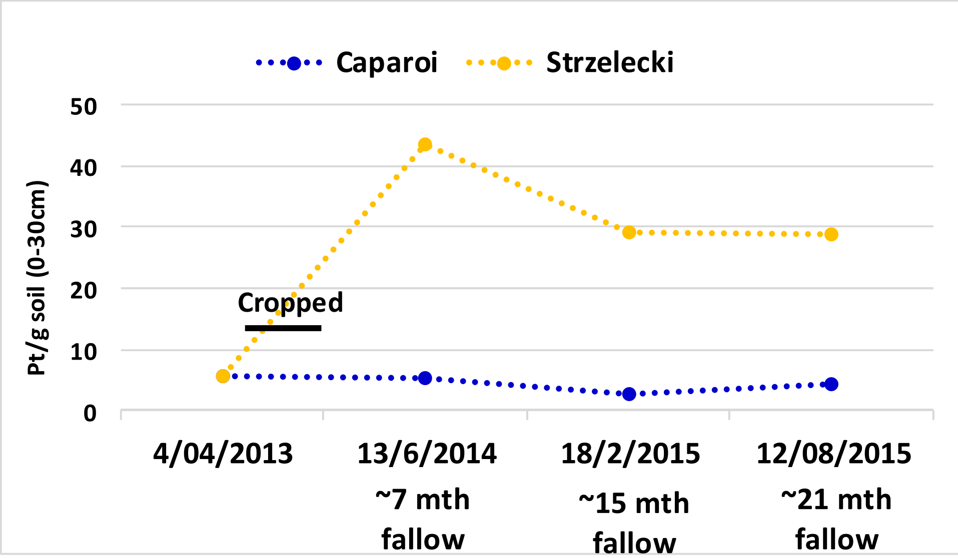


Figure 1. *Pt* population change over time following either Caparoi or Strzelecki production in 2013

Trial activity 2015

A total of 14 different trials of the major winter cereal and broadleaf cropping options were evaluated as split plot trials. Seed size and % germination were assessed for all seed lots with sowing rates adjusted to plant equivalent numbers of viable seeds for each crop. All crops received Granulock Z Xtra at 40kg/ha. Commercial crop protection products (and chipping) were used to manage weeds, foliar diseases and insect pressure.

There were four replicates in all trials with the exception of the faba bean and canola trials where eight replicates were included due to the limited number of treatments. Plots were sown at ~9m length x 5 rows on 36cm row spacing. Strips sown to Strzelecki in 2013 were described as having 'high' *Pt* pressure and the strips sown to Caparoi were described as having 'med' *Pt* pressure. **NB the population in the 'med' *Pt* pressure strips was still in excess of the widely used commercial 'threshold' of 2 *Pt*/g soil.**

Individual trial details are shown in Table 1. Trials LB1501- LB1503 and NVT trials were conducted as standard split plot trials comparing variety performance in the 'med' and 'high' Pt strips. Trials LB1504-LB1509 had additional factor(s) included.

Table 1. Key details of individual trials conducted in 2015

Trial description	Planting date	Number of varieties	Additional factors	Target plant stand/m^2
Minor crop resistance Screen	28/05/2015	8	-	-
Brassica evaluation	31/03/2015	6	-	30
Faba bean evaluation	15/05/2015	6	-	20
Chickpea NVT	28/05/2015	16		25
Chickpea potential nematicides		2	+/- seed treatment	25
Chickpea Deep P		2	+/- P fertiliser	25
Wheat Deep P		3	+/- P fertiliser	90
Wheat potential nematicides		2	+/- seed treatment	90
Wheat: impact of crown rot (CR)		7	+/- CR inoculum	90
Durum NVT		10	-	90
Main wheat NVT		36	-	90
Barley NVT		30	-	90
Early wheat NVT		24	-	90
Row spacing x Plant Population		2	2 row spacings, 2 plant populations	50 & 100

Trial assessments

Key in-crop assessments were establishment, ‘greenness’ (measured by NDVI), yield for all crops and grain quality for all cereals and brassicas.

Yield

The following graphs show the pattern of significant yield differences within varieties of the same crop between ‘med’ and ‘high’ *Pt* pressure. Significant yield differences within varieties were found in the early wheat, main wheat and durum NVT trials. Significant yield differences were also found in the *P thornei* x crown rot trial.

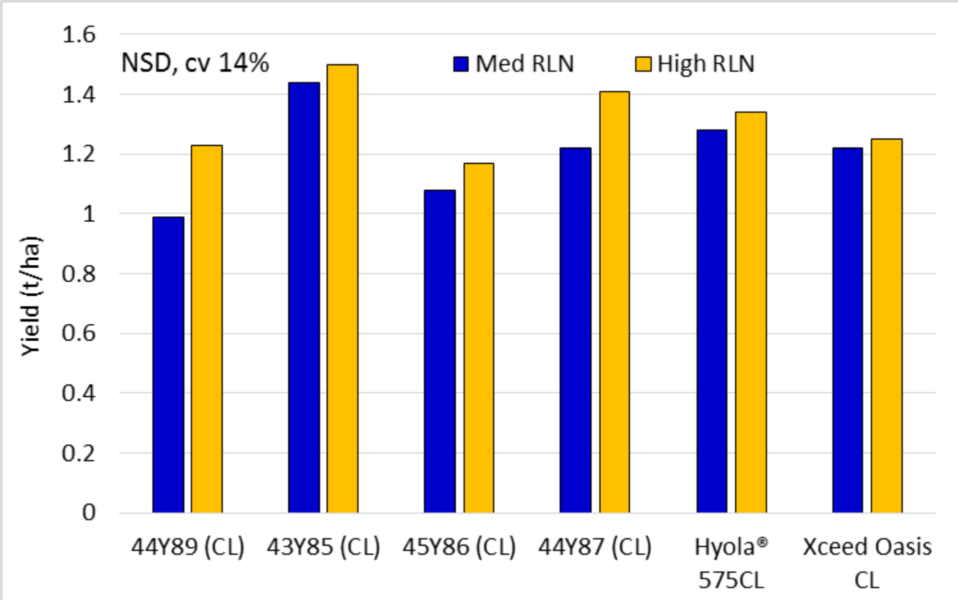


Figure 2. Brassica yields in the 'med' and 'high' *Pt* strips (all canola except the *B juncea* Xceed Oasis CL)

- There was no significant yield loss for any commercial variety between the 'med' and 'high' Pt strips.

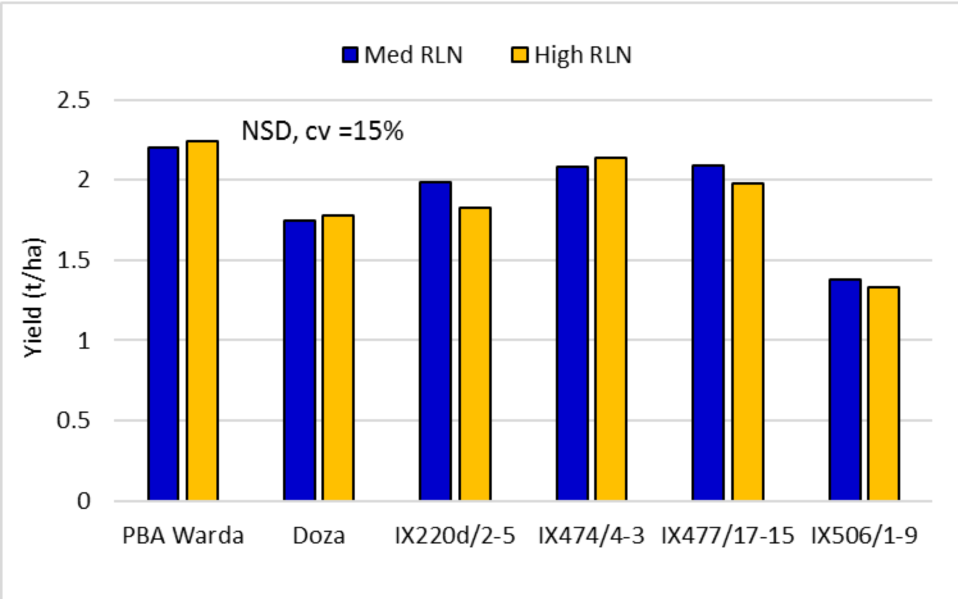


Figure 3. Faba bean variety yields in the 'medium' and 'high' *Pt* strips (Doza⟨D and PBA Warda⟨D are protected under the Plant Breeders Rights Act 1994)

- There was no significant yield loss for any commercial variety or line between the 'med' and 'high' Pt strips.
- High level of yield variability due to leaf rust and early crop senescence.

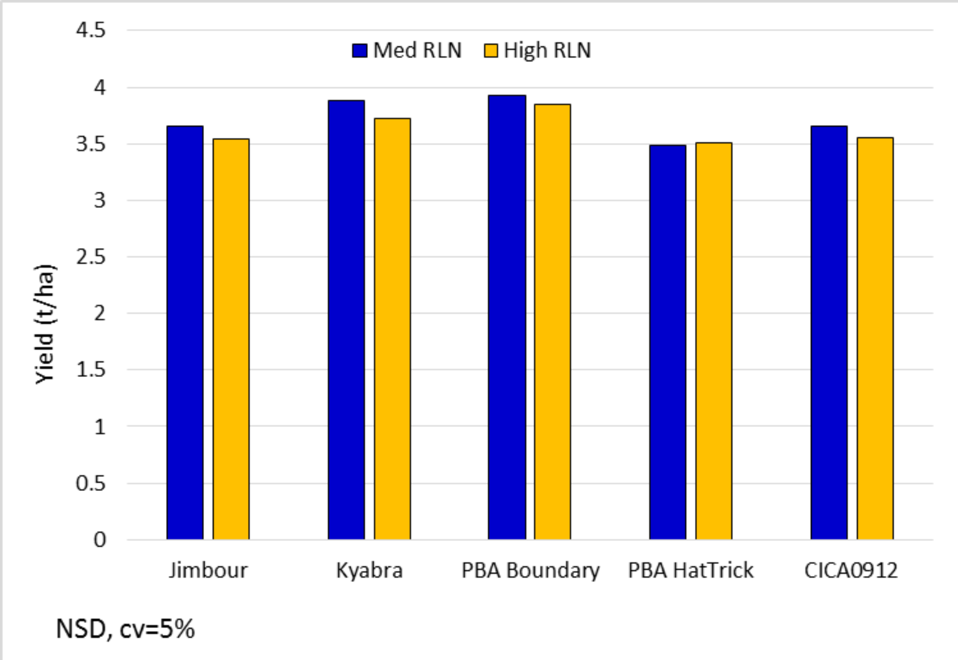


Figure 4. Chickpea yields for key lines in the 'med' and 'high' *Pt* strips (Kyabra⟮, PBA Boundary⟮ and PBA HatTrick⟮ are protected under the Plant Breeders Rights Act 1994)

- NB only the current commercial lines and next variety planned for release are graphed
- There was no significant yield loss for any commercial variety or line between the 'med' and 'high' Pt strips.

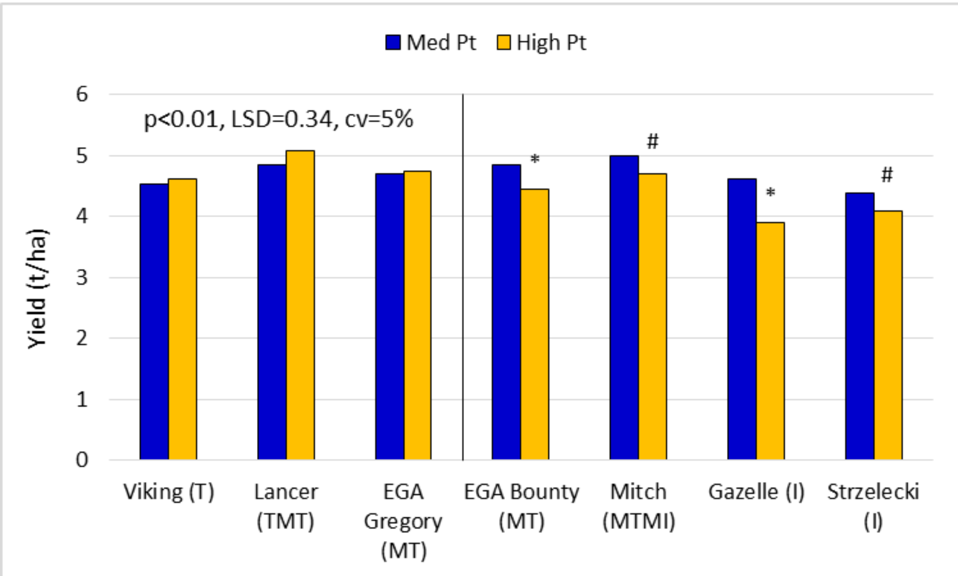


Figure 5. Early sown wheat yields for key lines in the 'med' and 'high' Pt strips. (Lancer⟮, EGA Gregory⟮, EGA Bounty⟮, Mitch⟮, Gazelle⟮ and Strzelecki⟮ are protected under the Plant Breeders Rights Act 1994)

*indicates the variety had a significant yield reduction in the 'high' *Pt* strips at p=0.05
# indicates the variety had a significant yield reduction in the 'high' *Pt* strips but only at p=0.10

NB the letter following the variety name indicates the *Pt* tolerance rating with the poorer rated varieties to the right of the solid vertical line. Varieties to the left of the vertical line are included for benchmarking purposes only.

- Mitch⟲, Gazelle⟲ and Strzelecki⟲ all recorded significantly lower NDVI readings in the 'high' *Pt* strips when assessed in September. EGA Bounty⟲ was significant at the 10% level
- All these varieties also recorded significant yield losses in the 'high' *Pt* strips at either the 5 or 10% level

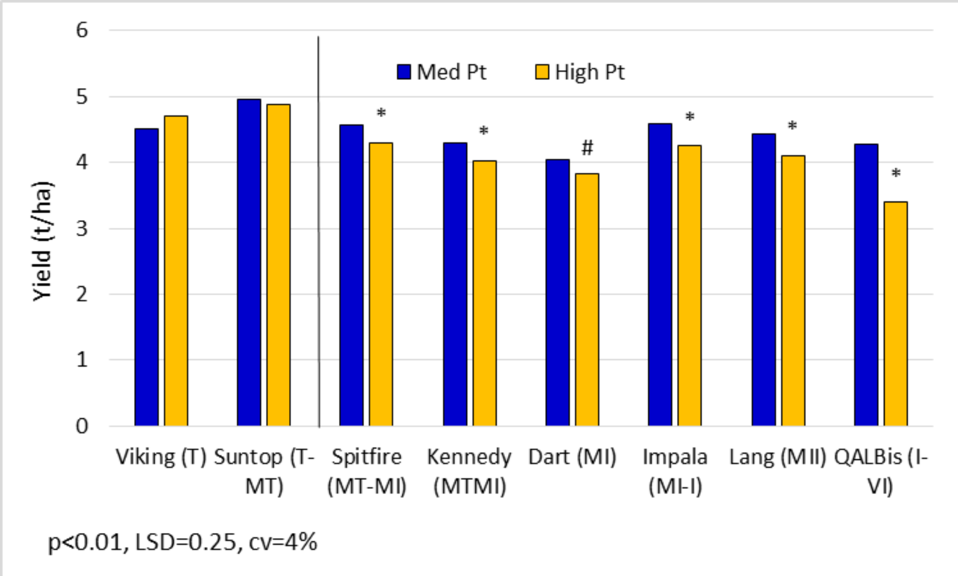


Figure 6. Main sown wheat yields for key lines in the 'med' and 'high' *Pt* strips.
(Suntop⟲, Spitfire⟲, Kennedy⟲, Dart⟲, Impala⟲and Lang⟲ are protected under the Plant Breeders Rights Act 1994)

*indicates the variety had a significant yield reduction in the 'high' *Pt* strips at p=0.05
# indicates the variety had a significant yield reduction in the 'high' *Pt* strips but only at p=0.10

NB the letter following the variety name indicates the *Pt* tolerance rating with the poorer rated varieties to the right of the solid vertical line. Varieties to the left of the vertical line are included for benchmarking purposes only.

- There were a larger number of varieties in the main sown wheat NVT that recorded significantly lower yield in the 'high' *Pt* strips
- In addition to the commercial lines in figure 6, four experimental lines also recorded significant yield losses

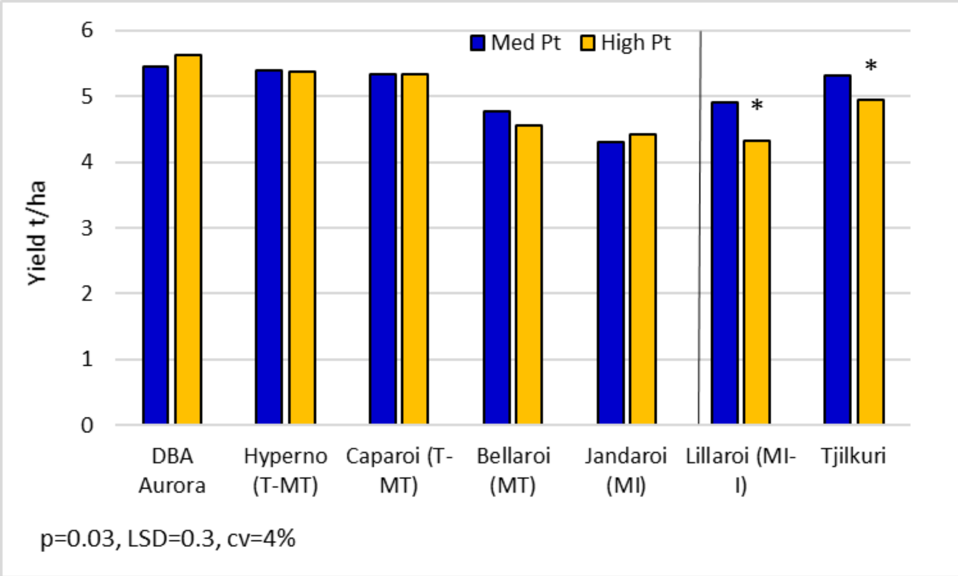


Figure 7. Durum yields for key lines in the 'med' and 'high' *Pt* strips.
(DBA Aurora⟨ⅾ⟩, Hyperno⟨ⅾ⟩, Caparoi⟨ⅾ⟩, Bellaroi⟨ⅾ⟩, Jandaroi⟨ⅾ⟩, Lillaroi⟨ⅾ⟩ and Tjilkuri⟨ⅾ⟩ are protected under the Plant Breeders Rights Act 1994)

*indicates the variety had a significant yield reduction in the 'high' *Pt* strips at p=0.05

NB. Varieties to the left of the vertical line are included for benchmarking purposes only with the poorer rated varieties for *Pt* effects to the right of the solid vertical line. The letter following the variety name indicates the *Pt t*olerance rating.

- Only two varieties within the durum NVT trial at this site recorded significant yield reductions when moving from 'med' to 'high' *Pt*.

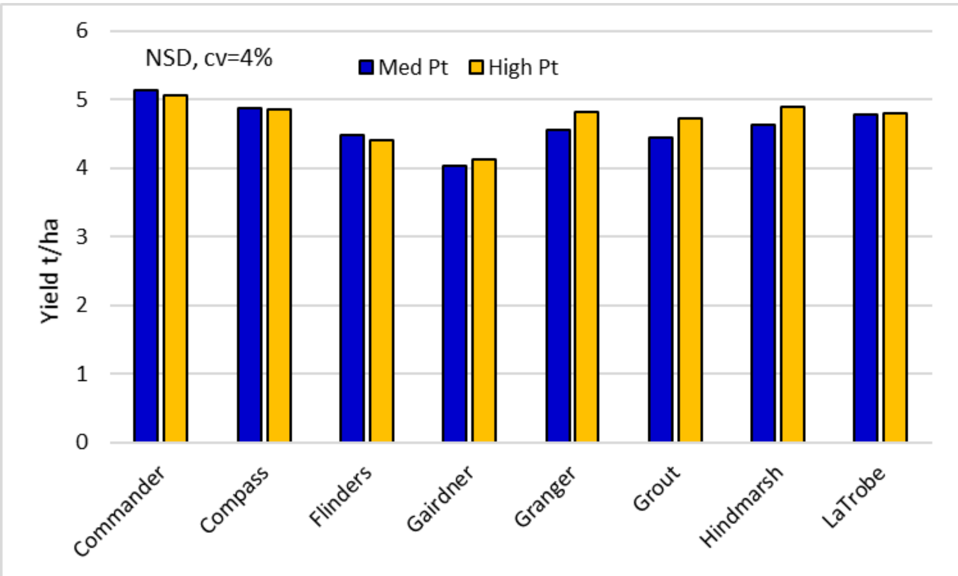


Figure 8. Barley yields for key lines in the 'med' and 'high' *Pt* strips.
(Commander⟨ⅾ⟩, Compass⟨ⅾ⟩, Flinders⟨ⅾ⟩, Granger⟨ⅾ⟩, Grout⟨ⅾ⟩, Hindmarsh⟨ⅾ⟩ and La Trobe⟨ⅾ⟩ are protected under the Plant Breeders Rights Act 1994)

- There was no significant yield loss for any commercial variety between the ‘med’ and ‘high’ *Pt* strips.
- The barley varieties tested appeared more tolerant than the range of wheat varieties sown at the same time

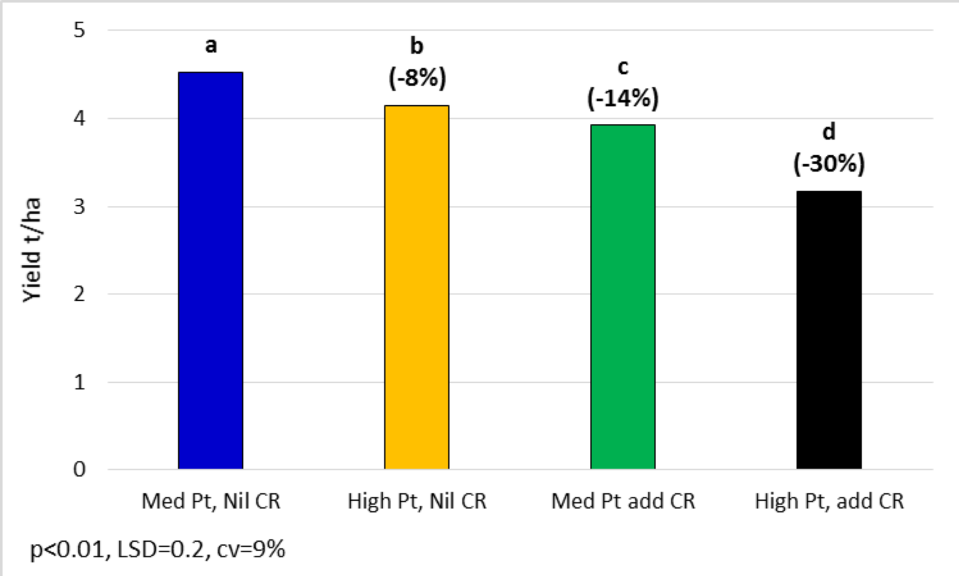


Figure 9. Wheat mean yields for six varieties with or without added crown rot (CR) inoculum. The six varieties include Spitfire⦶, Sungard⦶, EGA Gregory⦶, Sunmate⦶, Mitch⦶ and Elmore CL⦶.

Treatments that do not share the same letter are significantly different at p=.05

- When moving from ‘med’ *Pt* strips to ‘high’ *Pt* strips without adding CR, the mean yield reduction was 0.4t/ha over all six varieties.
- The addition of crown rot inoculum resulted in a mean yield loss of 0.6t/ha, while remaining under the ‘med’ *Pt* strips.
- When moving from ‘med’ *Pt* strips to ‘high’ *Pt* strips, in addition to adding crown rot inoculum, the mean yield reduction was 1.4t/ha over all six varieties.

Conclusions

This trial was conducted to allow a sound scientific evaluation of the impact of *Pt* on the yield of a broad range of winter crops and varieties and subsequently to measure the crop impact on *Pt* population (ie rotational impact and fit). Trial results indicate that there was no significant difference in yield within varieties of canola, faba bean, chickpea and barley between low versus high nematode populations. However, significant yield reductions were recorded for varieties in the early wheat, main wheat and durum NVT’s. In addition, significant yield losses were also recorded in the CR x RLN interaction trial.

Data still to come

Soil coring to determine the impact of the crops and varieties on *Pt* multiplication (the second key trial aim) will be conducted in early 2016. Grain quality analysis is also planned to take place in early 2016. Dual EM readings have been taken from all treatment plots to estimate the remaining soil water after harvest.

Acknowledgements

This was an exceptional trial in both size and complexity but also in the way it was managed. Sincere thanks to Rob Taylor and DAF Qld for field trial activity and their ability to successfully manage the multi-crops grown. Thanks also to AGT, BASF, Austgrains, Pacific Seeds, Pioneer, University of Sydney PBI, Seedmark, and Seednet for providing seed or inoculants.

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

Contact details

Brendan Burton
Northern Grower Alliance
Level 1, 292 Ruthven Street Toowoomba 4350
Ph: 0428 979 170
Email: brendan.burton@nga.org.au

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

Root-lesion nematodes (*Pratylenchus thornei*): how long does it take to reduce their population within the soil?

Jeremy Whish[1] and John Thompson[2]

[1]CSIRO Agriculture, 203 Tor Street, Toowoomba, QLD 4350, Australia

[2]Centre for Crop Health, Institute for Agriculture and the Environment, University of Southern Queensland, Toowoomba, Qld 4350, Australia

Key words

Root-lesion nematode (*Pratylenchus thornei)*; modelling population decline

GRDC code

CSE00055

Take home message

- Know your soil's Root-lesion nematode (*P. thornei*) population size
- Test your soil for Root-lesion nematodes. *P. thornei* populations greater than 40,000 per kg at harvest will requires a double break of around 40 months free of a host to reduce the population below the accepted threshold of 2000 Pt/kg. *P. thornei* populations greater than 10,000 per kg at harvest will requires a single break of around 30 months free of a host to reduce the population below the accepted threshold of 2000 Pt/kg.
- Weeds can be a host so fallows must be weed free and free of volunteers

Background

The root-lesion nematode *Pratylenchus thornei* (Pt) is a major pest of cereal and pulse crops on the heavy clay textured soils of the northern grains region of eastern Australia. *P. thornei* has a broad host range covering many cereals and pulses (Castillo and Vovlas, 2007; Nicol and Rivoal, 2008) highlighting its economic importance as a major pathogen of grain production worldwide. In Australia, yield losses in intolerant wheat varieties as a result of *P. thornei* have been estimated at between 44 and 80% (Thompson, 2008; Thompson et al., 2012), resulting in an estimated annual cost to the industry of $38 million (Murray and Brennan, 2009). Genetic control by breeding tolerant and resistant varieties has been considered the best long-term approach for this pathogen (Thompson et al., 1999). Wheat lines with superior tolerance have been developed, which has meant the regional wheat yield potential has continued to be achieved. However, tolerant varieties can continue to increase the nematode population, creating high pathogen levels in the soil and posing a serious risk to other host crops that do not have tolerant or resistant lines available.

How long does it take a *P.thornei* population to decline in the absence of a host.

Fallowing or the use of consecutive non-host crops such as sorghum(O'Brien, 1983) has the potential to significantly reduce *P. thornei* populations (Owen et al., 2014; Thompson et al., 2012) . However, this can take a long time and never completely eliminate the pest as low numbers of *P. thornei* were still present in soils fallowed continuously for 8 years (Peck et al., 1993). This is in contrast to another *Pratylenchus* species (*P. coffeae*) where an 11-month absence of a host reduced the population to zero (Trinh et al., 2011). To understand the rate of decline in a nematode population we monitored different starting populations for a 30 month host free period in a Vertosol on the Darling Downs at Formartin.

What we did

Following two consecutive wheat crops using wheat cultivars with different levels of tolerance and resistance a range of nematode populations were created in the soil. At the harvest of the second wheat crop the nematode population from each plot was recorded and characterised as high, (H >20,000Pt/cm^2/1.2m profile), medium (M >10,000Pt/cm^2/1.2m profile), low (L >5,000Pt/cm^2/1.2m profile) and very low populations (VL <5,000Pt/cm^2/1.2m profile) calculated as the sum of nematodes across the whole profile. Over the next 30 months, soil samples were collected from these plots to monitor the change in nematode population over time. Two 1.8 m soil cores were collected from each plot and divided into 8 layers (the top four being of 15 cm and the bottom four of 30 cm) Nematodes were extracted from the soil and manually counted to give a live nematode population estimate for each soil layer. The rotation over the 30 months was, long fallow from wheat to sorghum then long fallow from sorghum to wheat. In the fallow commencing in 2011 no sorghum was sown due to drought.

Our results

In this experiment, the majority of nematodes resided in the soil surface layers. Over the 30 months without a host crop the bulk of the populations reduced to below the damage threshold of 2000/kg or ~2/cm^3. The majority of the reduction occurred in the surface layers (Figure 1). The 0-15 cm layer at the surface showed the fastest decline in population numbers (Figure 2).

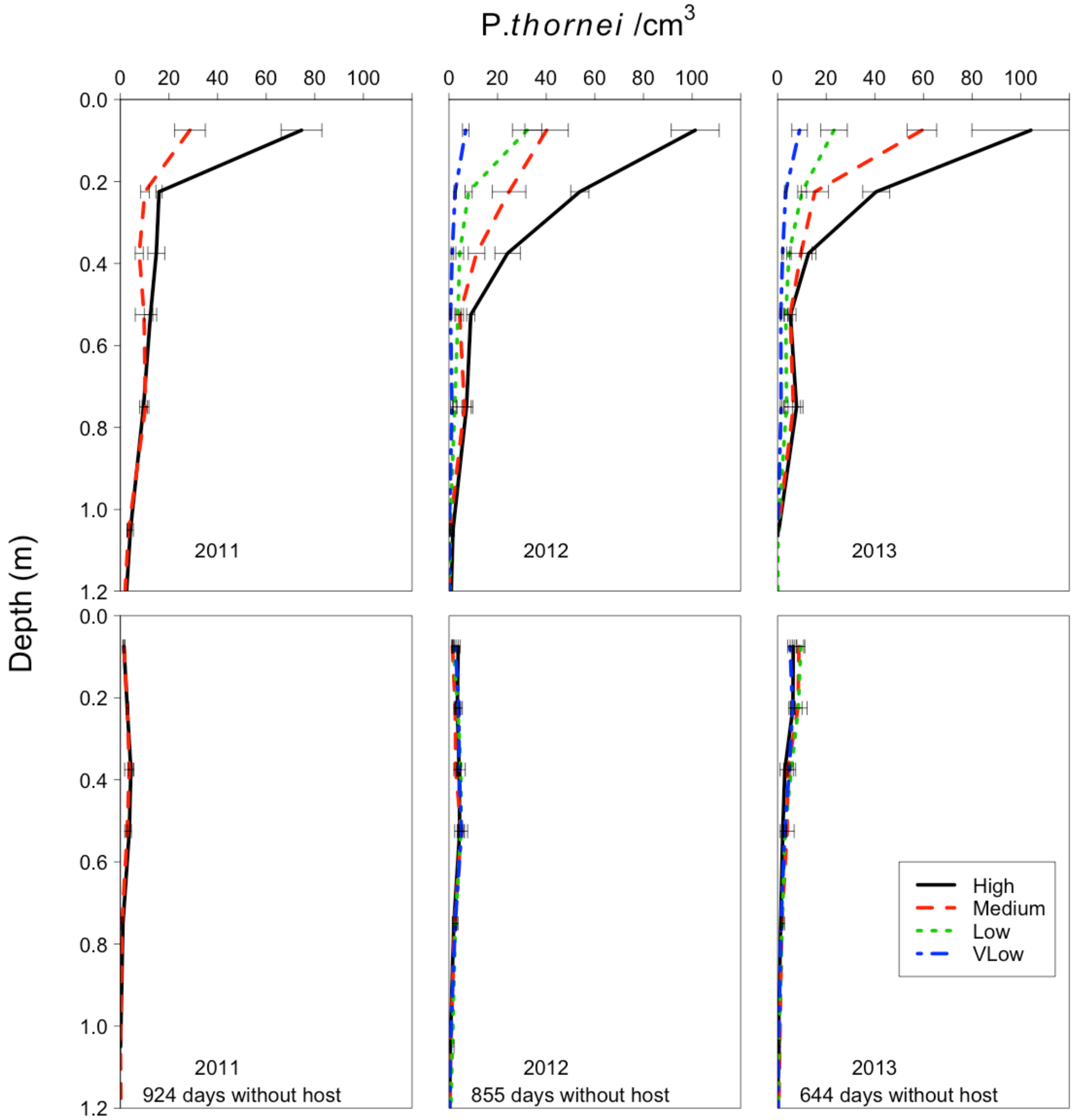


Figure 1. Distribution of *Pratylenchus thornei* at the start (top row) and end (bottom row) of the three non-host long fallows. The different lines indicate the different starting population classes (High,H >20,000Pt/cm^2/1.2m profile), medium (M >10,000Pt/cm^2/1.2m profile), low (L >5,000Pt/cm^2/1.2m profile) and very low population (VL <5,000Pt/cm^2/1.2m profile) calculated as the sum of nematodes across the whole profile. Standard errors are indicated for each sampling point.

To understand the rate of decline or how many nematodes died per day a negative exponential function was applied to the data (Figure 2) which went part way to describe the observed data. Note how a sharp drop occurs in the surface layer but not in the second or third layer population densities.

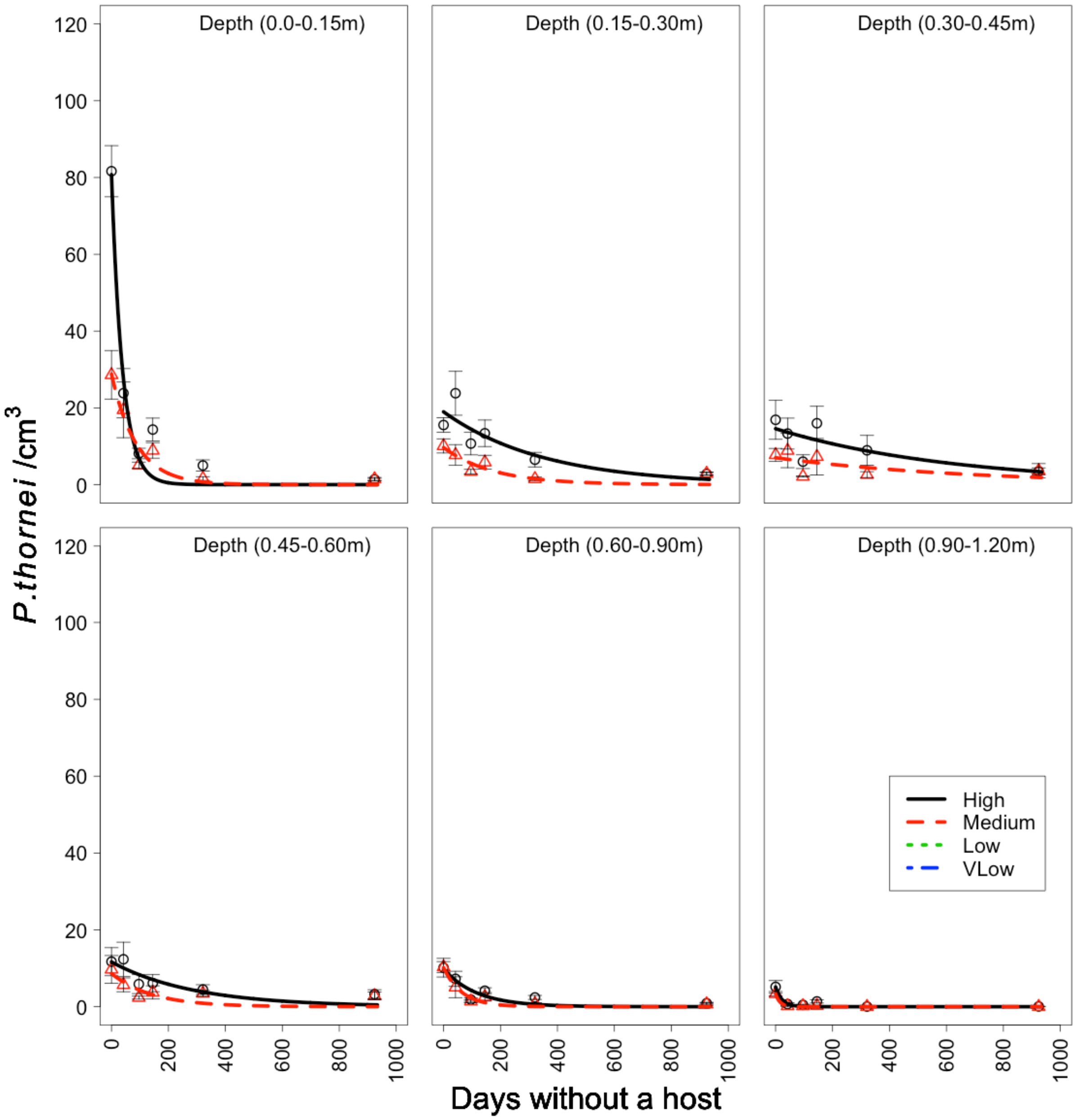


Figure 2. The negative exponential function Y=ae-bt, where y = nematode density per soil layer, t = time in days , a = the intercept and b = the slope parameter, fitted to the high and medium population data at each soil layer over the 30-month fallow commencing in November 2011. Standard errors are presented for each of the observed population measurements.

A similar rate of decline was found in each of the non-host periods for each layer. This information was combined with knowledge of temperature and moisture to build a dynamic nematode decline model that worked with APSIM. The completed model was tested against the observed data. The observed predicted regression (Figure 3) shows the model accounted for 95% of the error. The predicted model curves highlight how the inclusion of dynamic modelling or temperature and moisture combined with age class mortality rates of the different nematode life stages improved the prediction in the early stages of the fallow (Figure 4).

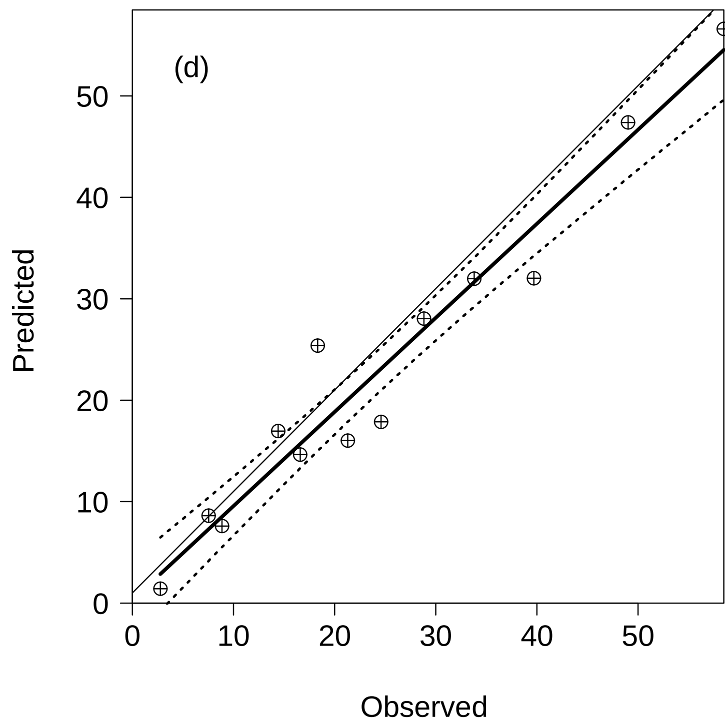


Figure 3. The observed predicted regression (Fig. 1d) shows good correlation between the observed and predicted data, y = 0.93x + 0.28, R2=0.94.

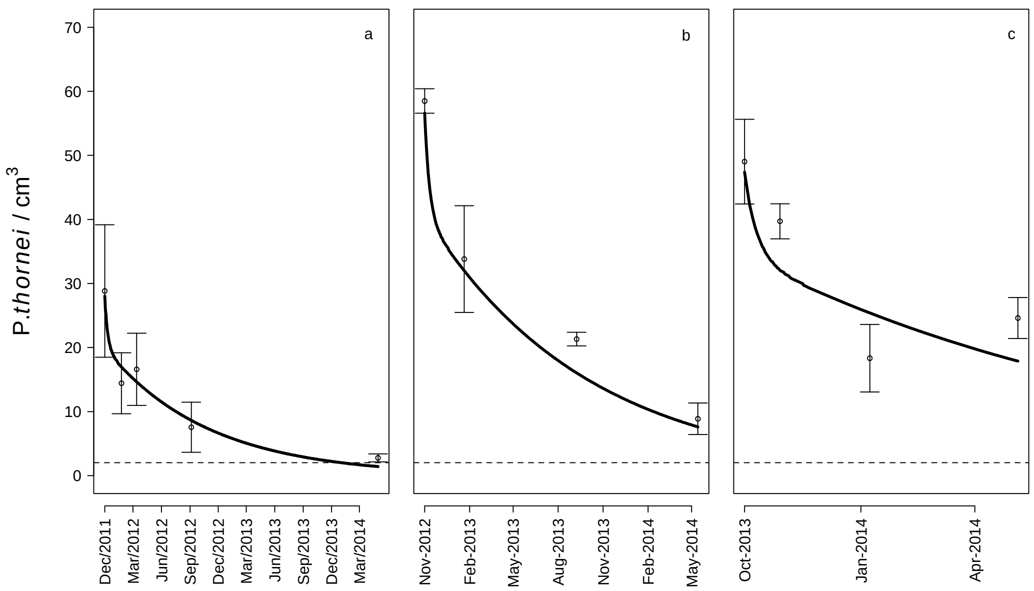


Figure 4. The observed (points) and predicted (line) population data declining from maximum population at harvest of the preceding wheat crop and the decline over the break. The longest decay curve (a) included a non-host sorghum crop sown in October 2012. The shorter curve (b) commenced in November 2012 and there was no sorghum crop planted due to drought. The final curve (c) commenced in 2013 and had a sorghum crop planted in October 2014. The dashed horizontal line represents the damage threshold below which minimal yield loss will occur in a susceptible wheat crop.

Using the developed model, the time taken to reduce different sized nematode populations to below the damage threshold of 2000 nematodes per kg was calculated (Figure 5).

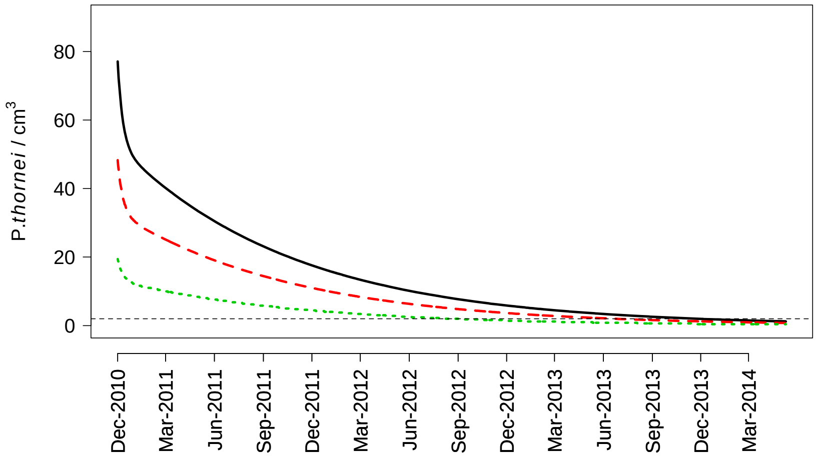


Figure 5. The effect of starting population (80 Pt/cm^3 ~80,000/kg, solid black line; 50 Pt/cm^3 ~50,000/kg, dashed red line; 20 Pt/cm^3 ~20,000/kg , dotted green line) on the time taken for the *P. thornei* population to reduce below the economic threshold.

So what?

The scenario analysis (Figure 5) highlighted the importance of the initial population when reducing nematode populations below the damage threshold. High population of 80 nematodes per cm^3 (~80,000 Pt/kg) took four years to reduce below the threshold. This would require 2 non host crops such as sorghum and fallows to reduce the population. A moderate initial population of 50 nematodes per cm^3 took three and a half years (Figure 6), requiring the equivalent of a single non host summer crop and fallows. A population of 20 nematodes per cm^3 took 24 months. The long survival mechanisms of root-lesion nematodes highlight the importance of knowing the size of the population at the end of each season. Once a population increases, non-host, resistant crops or fallows are required to reduce the population below the damage threshold. Planting susceptible or tolerant crops within this time period will increase populations to higher levels that will take longer to reduce, thereby limiting cropping options, and potentially reducing the profitability of the overall farming system. As resistant wheat varieties are released they can be used to provide a winter decline option to increase non-host periods within the rotation.

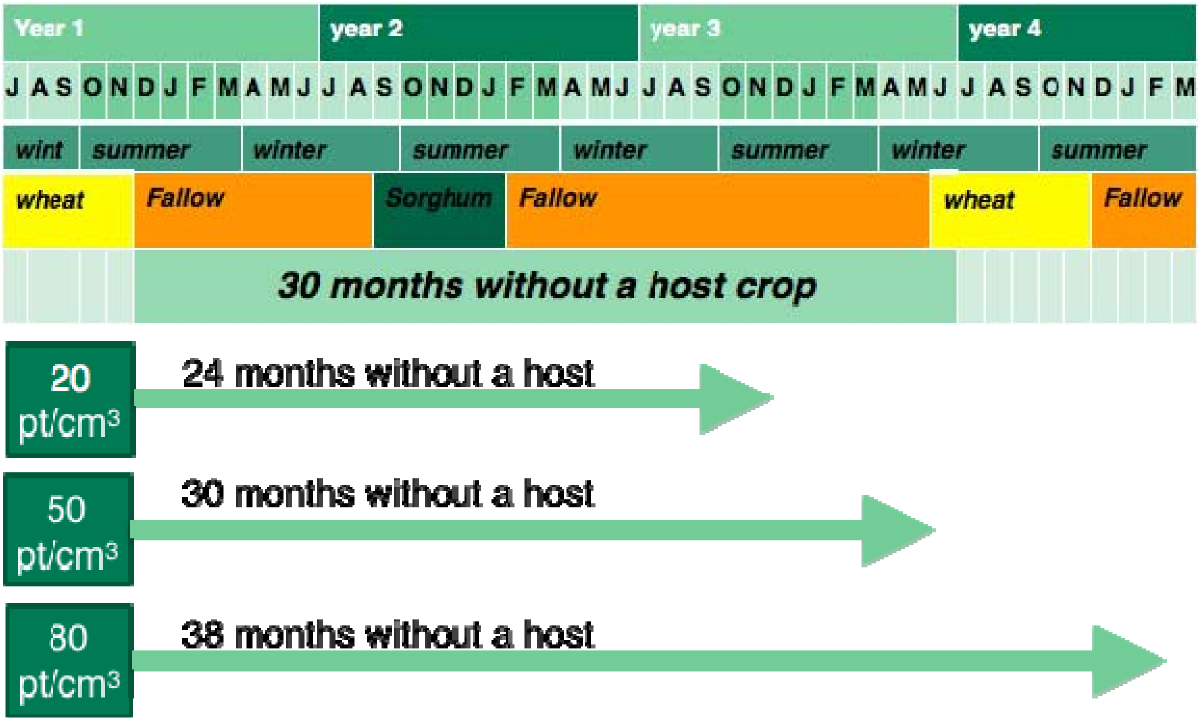


Figure 6. An example of a non-host fallow showing the time required to reduce different starting populations of root-lesion nematode.

Where to next

Further testing of the model is required to ensure it captures the influences of different soils, soil temperatures and moisture conditions. Understanding the survival mechanisms of *P. thornei* and what causes the initial sharp decline may provide some insight into tactical ways to reduce populations faster and maintain low populations for longer

References

Castillo P., Vovlas N. (2007*) Pratylenchus* (Nematoda: Pratylenchidae): Diagnosis, biology, pathogenicity and management. Chapter 7. In *Biology and ecology of* Pratylenchus. Nematology Monographs and Perspectives Series 6. pp. 305–324 Eds D.J. Hunt, R.N. Perry, Leiden-Boston:Brill,.

Murray, G.M., Brennan, J.P., 2009. Estimating disease losses to the Australian wheat industry. Austral. Plant Pathol. 38, 558–570. doi:10.1071/AP09053

Nicol, J.M., Rivoal, R., 2008. Global Knowledge and its Application for the Integrated Control and Management of Nematodes on Wheat, in: Mukerji, K.G. (Ed.), Integrated Management and Biocontrol of Vegetable and Grain Crops Nematodes. Springer, pp. 251–283.

O'Brien, P., 1983. A Further Study on the Host Range of *Pratylenchus thornei*. Austral. Plant Pathol. 12, 1. doi:10.1071/APP9830001

Owen, K.J., Clewett, T., Bell, K., Thompson, J.P., 2014. Wheat biomass and yield increased when populations of the root-lesion nematode (*Pratylenchus thornei*) were reduced through sequential rotation of partially resistant winter and summer crops. Crop Pasture Sci. 65, 227–15. doi:10.1071/CP13295

Peck, D.M., Thompson, J.P., Clewett, T., Haak, M.I., 1993. The root lesion nematode *Pratylenchus thomei* survives extended clean fallows and build up quickly with wheat cropping, in:. Presented at the th Biennial APPS Conference Hobart, July -th,, pp. 29–32.

Thompson, J.P., 2008. Resistance to root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) in synthetic hexaploid wheats and their durum and *Aegilops tauschii* parents. Aust. J. Agric. Res. 59, 432. doi:10.1071/AR07222

Thompson, J.P., Brennan, P., Clewett, T., Sheedy, J.G., Seymour, N., 1999. Progress in breeding wheat for tolerance and resistance to root-lesion nematode (*Pratylenchus thornei*). Austral. Plant Pathol. 28, 45–52.

Thompson, J.P., Zwart, R.S., Butler, D., 2012. Inheritance of resistance to root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) in five doubled-haploid populations of wheat. Euphytica 188, 209–219. doi:10.1007/s10681-012-0689-x

Trinh, P.Q., Wesemael, W.M.L., Nguyen, C.N., Moens, M., 2011. Decline of *Pratylenchus coffeae* and Radopholus arabocoffeae populations after death and removal of 5-year-old arabica coffee (*Coffea arabica* cv. Catimor) trees. Nematology 13, 491–500. doi:10.1163/138855410X528505

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, CSIRO and the University of Southern Queensland, and the authors would like to thank them for their continued support.

Contact details

Jeremy Whish
CSIRO
Ph: 07 46881419
Email: Jeremy.whish@csiro.au

Reviewed Neal Dalgliesh and Kirsty Owen

Drivers of fallow efficiency: Effect of soil properties and rainfall patterns on evaporation and the effectiveness of stubble cover

Kirsten Verburg[1], Jeremy Whish[2]

CSIRO Agriculture Canberra[1] and Toowoomba[2]

Key words

Plant Available Water (PAW), Plant Available Water Capacity (PAWC), fallow management, stubble retention

GRDC code

CSP00170 and past projects CSA00013 and ERM00002.

Take home message

- Soil properties (bulk soil and surface conditions) affect fallow efficiency through their effects on the different water balance terms.
- Rainfall patterns affect fallow efficiency as well as the effectiveness of stubble cover to reduce evaporation losses.
- The more limited effect of stubble retention on evaporation does not take away the benefits stubble cover provides in protecting the soil surface, increasing infiltration and reducing runoff and erosion.

Plant available water at sowing and fallow efficiency

Plant available water (PAW) at sowing will depend on water left behind by a previous crop, rainfall amount during the fallow and its distribution, efficiency of water infiltration (versus runoff), evaporation, water use (transpiration) by weeds, drainage beyond the root zone and in some cases subsurface lateral flow. Fallow efficiency, defined as the proportion of rain falling during the fallow period that becomes PAW, is similarly affected by these water balance terms (Figure 1).

Fallow management like stubble retention or weed control can change the magnitude of some of these water balance terms. In this paper we discuss how soil properties and rainfall patterns affect evaporation and the effectiveness of stubble cover.

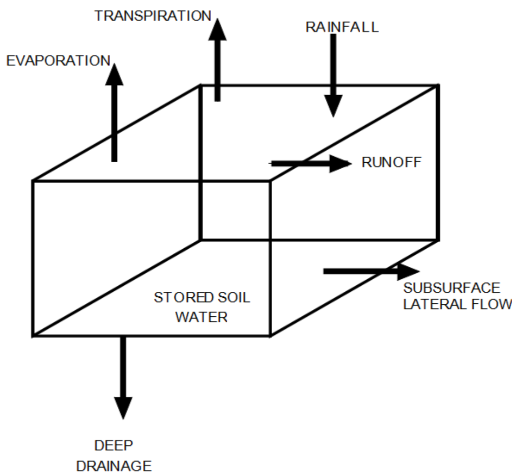


Figure 1. The relative magnitude of the different water balance terms determines the balance of inputs and losses and hence the fallow efficiency.

Impact of soil properties on evaporation

Just like soil properties affect the Plant Available Water Capacity (PAWC; see Verburg et al. paper in these proceedings), they also influence the magnitude of the different fallow water balance terms and hence PAW and fallow efficiency. The smaller particle size of clay soils allows them to hold larger quantities of water than sandy soils (i.e. lower drainage losses), but also causes the pore space (space between particles) to be finer. This reduces the water infiltration rate and can increase runoff losses, particularly in high intensity rainfall events and following prolonged rainfall. Soil surface conditions can, however, dramatically change this picture: open cracks in shrink-swell soils will aid infiltration, whereas surface sealing will increase runoff.

The higher PAWC of clay soils also means that water from small events is stored close to the soil surface where it will often be lost to evaporation if no follow up rain occurs. In sandy soils the water will infiltrate deeper into the profile.

Evaporation can dry the soil to below the crop lower limit in the surface layer. While this is a slow process in clay soils, the amount of rainfall needed to replenish this unavailable 'bucket' following a prolonged dry period will be larger in a clay soil than in a sandy soil. This is illustrated in Figure 2 where a sandy clay loam soil can hold 11.9 mm of water between the air-dry value and drained upper limit, but with only 8.7 mm available to the plant and an unavailable water capacity (UWC) of 3.2 mm. If evaporation had dried the soil to air dry and we had a 10mm rainfall event only 6.8 mm would be available for plant growth.

In contrast the heavy clay soil in Figure 2 holds 42mm between air dry and drained upper limit of which 20 mm is available for plant growth. In the same scenario as before, if the soil was dry and we had a 10 mm rainfall event there would be no water available for plant growth, unless it want down a deep crack into deeper and less dry soil. Over 22mm of rain needs to fall to fill the unavailable bucket in the surface of this soil. Fortunately, the fine structure of the heavy clay soil also means the unavailable bucket will take a long time to dry out, so that on many occasions only the upper layers of the soil will need to be refilled.

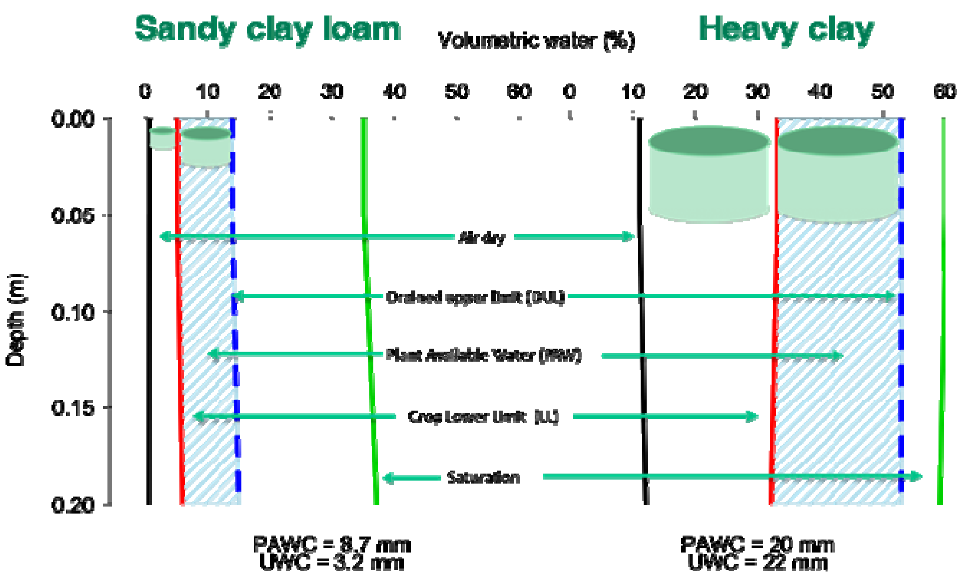


Figure 2. Conceptual diagram of the difference in unavailable water bucket size (UWC) in the surface 20 cm of a sandy clay loam and a heavy clay soil

Impact of rainfall pattern

The interaction between depth of infiltration and susceptibility to evaporation loss also plays a role in determining the effectiveness with which rainfall is turned into PAW for the subsequent crop. Unless runoff is an issue, large rainfall events will infiltrate deeper than small events, allowing some of the water to be pushed below the evaporation zone and contribute to PAW at sowing. Single, isolated rainfall events have, however, typically a lower efficiency than more frequent events. When two or more rainfall events occur closely together, the resulting soil water 'pulses' can build on each other (Figure 3). The amount of water needed to refill the unavailable bucket in the surface layer (following evaporation) is reduced, thereby allowing the water to move deeper into the profile.

The amount of overlap between soil water 'pulses' is affected by a balance between pulse frequency and pulse duration. Rainfall frequency is the driver behind pulse frequency, whereas pulse duration is affected by the amount of infiltrated rainfall, evaporative demand, stubble cover and soil type.

The above illustrates why the same amount of rainfall can result in different fallow efficiencies. Surface conditions can, however, complicate the picture. Surface sealing following multiple or prolonged rainfall events can reduce the infiltration rate and increase runoff. Conversely, a single large storm on a dry cracking clay soil can infiltrate deeper via the open cracks.

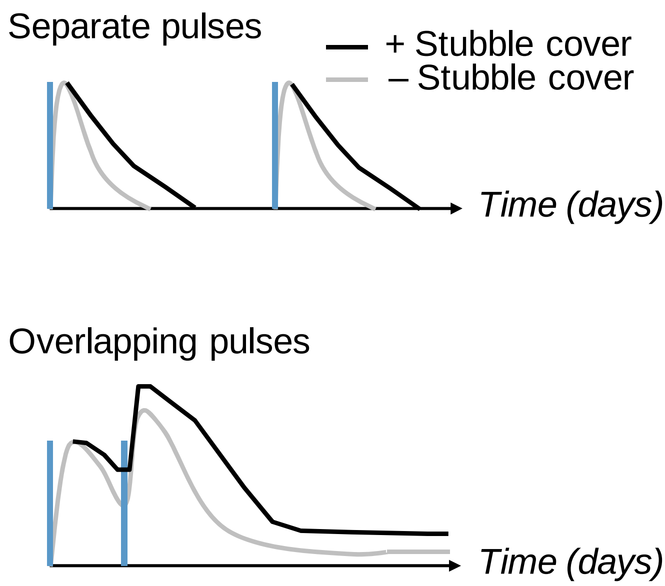


Figure 3. Rainfall events (vertical blue bars) cause pulses of soil water that last for different amounts of time in the presence (black lines) or absence (grey lines) of stubble. When pulses overlap, more water infiltrates beyond the evaporation zone in the presence of stubble cover and this will increase fallow efficiency. (Adapted from Verburg et al. 2010)

Impact of rainfall pattern on the effectiveness of stubble to reduce evaporation

While rainfall pattern effects are beyond our control, fallow efficiency can be maximised by reducing the losses. Several trials in recent years have demonstrated that weed control dramatically reduces transpiration losses (e.g. Hunt et al. 2011; Routley 2010) and that stubble retention increases infiltration and hence reduces runoff losses (Whish et al. 2009; Hunt et al. 2011). The effect of stubble and stubble management (e.g. standing vs. flattened stubble) on reducing evaporation losses has, however, often disappointed people with many trials returning no significant treatment effects (e.g. Scott et al. 2010; Hunt et al. 2011; Hunt 2013). The exception is when large amounts of stubble are concentrated on a smaller area to create high loads (Hunt et al. 2011).

The observed limited effectiveness of stubble cover to reduce evaporation losses can be explained using the same concept of soil water pulses. The high evaporative demand experienced during summer in Australia limits the duration of the soil water pulses. In the case of sparse rainfall events this allows the system with stubble cover to 'catch up', despite the initial reduction in evaporation. Freebairn et al. (1987) showed this experimentally in soil evaporation studies using shallow weighing lysimeters. Stubble cover slowed evaporation for around 3 weeks following rainfall, but there was no longer term benefit to soil moisture levels. If the next rainfall event occurs prior to the system catching up, soil water will move deeper in the system with stubble cover and may store (more) water beyond the nominal evaporation zone. A higher level of stubble cover (as in experiments by Northern Grower Alliance, 2015) will prolong the duration of the soil water pulse, increasing the chance of events overlapping and of causing a lasting increase in PAW. In the event of small, isolated rainfall events, high loads of stubble may be detrimental to overall PAW with the water captured in the stubble layer and prone to evaporation.

As shown in Figure 3, evaporative demand plays a role too. A lower evaporative demand will lengthen the duration of soil water pulses and hence increase the chance of pulses to overlap. Indeed simulations as well as data from lysimeter experiments near Wagga Wagga by Verburg et al. (2012) showed that stubble cover later in autumn and early winter (when evaporative demand was lower and rainfall frequency higher) did cause a significant reduction in evaporation (10-15 mm over an 8-week period following sowing into a stubble load of 4 t/ha while differences over the preceding 4 months during summer were only 3-4 mm).

Final remarks

Understanding the drivers of fallow efficiency and awareness of the particular conditions experienced during the fallow will assist in explaining observed PAWs and predict which fallow seasons may have higher or lower fallow efficiency. When using PAW to inform management decisions, it is, however, recommended to confirm actual PAW levels through measurement (soil core, push probe).

While this paper specifically discussed the evaporation loss term of the water balance, it should be noted that the more limited effect of stubble retention on evaporation does not take away the benefits stubble cover provides in protecting the soil surface, increasing infiltration and reducing runoff and erosion.

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. The concepts and findings presented in this paper were developed as part of GRDC projects CSP00170, CSP00111, CSA00013 and ERM00002.

References

Freebairn, D.M., Hancock, N.H. and Lott, S.C. (1987), Soil evaporation studies using shallow weighing lysimeters: Techniques and preliminary results, Trans. Mech. Engn., Inst. Engn. Australia, Vol. ME12. pp 67-72.

Hunt J et al. (2011) Summer fallow management. GRDC Update paper. https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/02/Summer-fallow-management

Hunt J (2013) Control summer weeds to reap yield benefits. Ground Cover Supplement-Water Use Efficiency, edited by J Paterson. Grains Research and Development Corporation, Canberra. March-April 2013. ISBN 1039-6217.

Northern Grower Alliance (2015) Stubble impact on fallow water efficiency in western zones 2014/15. Project report – Results in a nutshell. http://www.nga.org.au/results-and-publications/download/356/project-reports-general/results-in-a-nutshell/stubble-impact-on-fallow-water-efficiency-2014-15.pdf

Routley R (2010) Water use efficiency – Optimizing farming systems performance and balancing fallow length and sowing decisions. GRDC Update paper. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/water-use-efficiency-optimizing-farming-systems-performance-and-balancing-fallow-length-and-sowing-decisions

Scott BJ, Eberbach PL, Evans J and Wade LJ (2010) Stubble Retention in Cropping Systems in Southern Australia: Benefits and Challenges. EH Graham Centre Monograph Series Monograph No. 1 (http://www.csu.edu.au/research/grahamcentre/research/publications/stubble-retention-SA.htm)

Verburg K, Bond WJ, Hunt JR (2010) Variable soil water accumulation under fallow management: Explanation using a pulse paradigm. In "Food Security from Sustainable Agriculture" Edited by H. Dove and R. A. Culvenor Proceedings of 15th Agronomy Conference 2010, 15-18 November 2010, Lincoln, New Zealand.

Verburg K, Bond WJ, Hunt JR (2012). Fallow management in dryland agriculture: Explaining soil water accumulation using a pulse paradigm. Field Crops Research 130, 68-79.

Whish, J.P.M., Price, L., Castor, P.A., 2009. Do spring cover crops rob water and so reduce wheat yields in the northern grain zone of eastern Australia? Crop Pasture Science 60, 517–525.

Contact details

Kirsten Verburg
CSIRO Agriculture
Ph: (02) 6246 5954
Email: kirsten.verburg@csiro.au

Jeremy Whish
CSIRO Agriculture
Ph: (07) 4688 1419
Email: Jeremy.whish@csiro.au

Methods and tools to characterise soils for plant available water capacity

Kirsten Verburg[1], Brett Cocks[2], Tony Webster[3], Jeremy Whish[2]

CSIRO Agriculture Canberra[1], Toowoomba[2], and Cairns[3]

Key words

Soil characterisation, Plant Available Water Capacity (PAWC), Plant Available Water (PAW), APSoil, soil-landscape, fallow management, APSIM.

GRDC code

CSP00170

Take home messages

- Information regarding the plant available water (PAW) at a point in time, particularly at planting, can be useful in a range of crop management decisions. Estimating PAW, whether through use of a soil water monitoring device or a push probe, requires knowledge of the plant available water capacity (PAWC) and/or the Crop Lower Limit (CLL).
- A wide variety of soils in the northern region have been characterised for PAWC and the characterisations are publicly available in the APSoil database, which can be viewed in Google Earth and in the 'SoilMapp' application for iPad.
- The field-based method for characterising PAWC has been tried and tested across Australia, but users need to be mindful of common pitfalls that can cause characterisation errors.
- Knowledge of physical and chemical soil properties like texture or particle size distribution and (sub) soil constraints helps interpret the size and shape of the PAWC profiles of different soils. It can also assist in choosing a similar soil from the APSoil database.
- Extrapolating from the point-based dataset to predict PAWC at other locations of interest is a challenge that needs further research. Preliminary analyses drawing on soil landscape mapping (NSW) and land resource area (LRA) mapping (Queensland) suggest that an understanding of position in the landscape and the story of its development may assist with extrapolation. This is because in many landscapes the soil properties determining PAWC are tightly linked to a soil's development and position in the landscape and these same aspects underpin soil and land resource surveys.
- While the concept of using soil-landscape information to inform land management is not new (e.g. Queensland land management manuals draw on the same concept), the availability of these maps on-line makes them more accessible and assists with visualising a location's position in the landscape. Combining these maps with the geo-referenced APSoil PAWC characterisations will increase the value that both resources can provide to farmers and advisors.
- Uncertainty of PAWC estimates translates into uncertainty in PAW. The extent to which this affects potential decision making depends on the question asked, but also needs to be viewed in terms of the spatial variability in PAW and the accuracy of the method to convert this water into a yield forecast.

Plant available water and crop management decisions

A key determinant of potential yield in dryland agriculture is the amount of water available to the crop, either from rainfall or stored soil water. In the northern region the contribution of stored soil water to crop productivity for both winter and summer cropping has long been recognized. The amount of stored soil water influences decisions to crop or wait (for the next opportunity or long fallow), to sow earlier or later (and associated variety choice) and the input level of resources such as nitrogen fertiliser.

The amount of stored soil water available to a crop - Plant Available Water (PAW) – is affected by pre-season and in-season rainfall, infiltration, evaporation and transpiration. It also strongly depends on a soil's Plant Available Water Capacity (PAWC), which is the total amount of water a soil can store and release to different crops. The PAWC, or 'bucket size', depends on the soil's physical and chemical characteristics as well as the crop being grown.

Over the past 20 years, CSIRO in collaboration with state agencies, catchment management organisations, consultants and farmers has characterised more than 1000 sites around Australia for PAWC. The data are publicly available in the APSoil database, including via a Google Earth file and in the 'SoilMapp' application for iPad (see Resources section).

A number of farmers and advisers, especially in the southern Australia, are using the PAWC data in conjunction with Yield Prophet® to assist with crop management decisions. Yield Prophet® is a tool that interprets the predictions of the APSIM cropping systems model. It uses the information on PAWC along with information on pre-season soil moisture and mineral nitrogen, agronomic inputs and local climate data to forecast, at any time during the growing season, the possible yield outcomes. Yield Prophet® first simulates soil water and nitrogen dynamics as well as crop growth with the weather conditions experienced to date and then uses long term historical weather record to simulate what would have happened from this date onwards in each year of the climate record. The resulting range of expected yield outcomes can be compared with the expected outcomes of alternative varieties, time of sowing, topdressing, etc. to inform management decisions.

Others use the PAWC data more informally in conjunction with assessments of soil water (soil core, soil water monitoring device or depth of wet soil with a push probe) to estimate the amount of plant available water. Local rules of thumb are then used to inform the management decisions.

The APSoil database provides geo-referenced data (i.e. located on a map), but the PAWC characterisations are for points in the landscape. To use this information one needs to find a similar soil. This is not a straight forward process and subject of ongoing research, but a number of data and information sources are available that can assist. If suitable PAWC data are not found, local measurement of PAWC is required. This will often also provide a more accurate estimate although spatial variability may still be an issue.

This paper describes the measurement of PAWC, including practical tips and pitfalls, and outlines where to find existing information on PAWC. It discusses the principles behind extrapolation from known soil profiles and illustrates this with examples of PAWC data for local soils.

Plant Available Water Capacity (PAWC)

To characterise a soil's PAWC, or 'bucket size', we need to determine (Figure 1a):

- drained upper limit (DUL) or field capacity – the amount of water a soil can hold against gravity;
- crop lower limit (CLL) – the amount of water remaining after a particular crop has extracted all the water available to it from the soil; and
- bulk density (BD) – the density of the soil, which is required to convert measurements of gravimetric water content to volumetric water content

In addition, soil chemical data are obtained to provide an indication whether subsoil constraints (e.g. salinity, sodicity, boron and aluminium) may affect a soil's ability to store water, or the plant's ability to extract water from the soil.

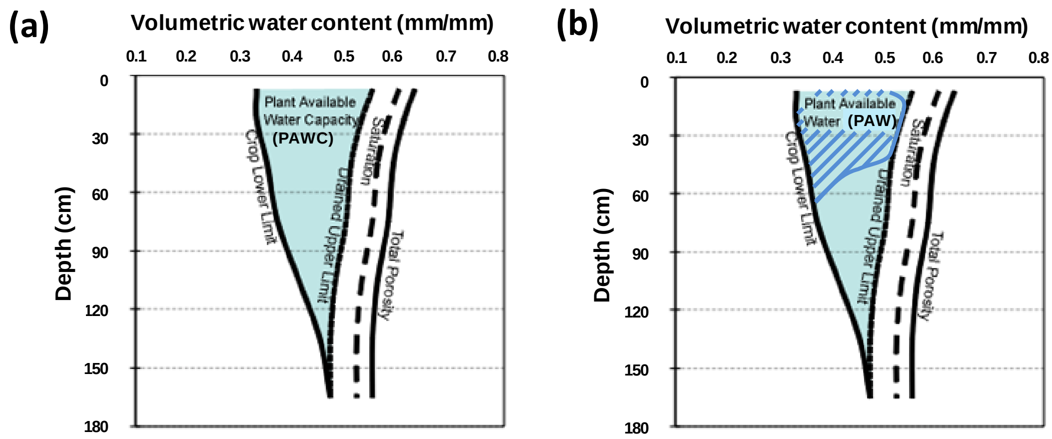


Figure 1. (a) The Plant Available Water Capacity (PAWC) is the total amount of water that each soil type can store and release to different crops and is defined by its Drained Upper Limit (DUL) and its crop specific crop lower limit (CLL); (b) Plant Available Water (PAW) represents the volume of water stored within the soil available to the plant at a point in time. It is defined by the difference between the current volumetric soil water content and the CLL.

Plant Available Water (PAW)

Plant available water is the difference between the CLL and the volumetric soil water content (mm water / mm of soil) (Figure 1b). The latter can be assessed by soil coring (gravimetric moisture which is converted into a volumetric water content using the bulk density of the soil) or the use of soil water monitoring devices (requiring calibration in order to quantitatively report soil water content).

An approximate estimate of PAW can be obtained from knowledge of the PAWC (mm of available water/cm of soil depth down the profile) and the depth of wet soil (push probe or based on a feel of wet and dry limits using an uncalibrated soil water monitoring device).

Knowledge of PAW can inform management decisions and many in the northern region have, formally or informally, adopted this. Several papers at recent GRDC Updates have illustrated the impact of PAW at sowing on crop yield in the context of management decisions (see e.g. Routley 2010, Whish 2014, Dalgliesh 2014 and Fritsch and Wylie 2015).

Field Measurement of PAWC

Field measurement of DUL, CLL and BD are described in detail in the GRDC *PAWC Booklet* 'Estimating plant available water capacity' (see Resources section). Briefly, to determine the DUL an area of approximately 4 m x 4m is slowly wet up using drip tubing that has been laid out in spiral (see Figure 2). The area is covered with plastic to prevent evaporation and after the slow wetting up it is allowed to drain (see GRDC *PAWC booklet* for indicative rates of wetting up and drainage times). The soil is then sampled for soil moisture and bulk density.

The CLL is measured either opportunistically at the end of a very dry season or in an area protected by a rainout shelter between anthesis/flowering and time of sampling (Figure 2). This method assumes the crop will have explored all available soil water to the maximum extent and it accounts for any subsoil constraints that affect the plant's ability to extract water from the soil.

Figure 2. Wetting up for DUL determination and rainout shelter used for CLL determination.

Pitfalls and common mischaracterization issues

While the concept of PAWC is simple and the measurement methods for DUL and CLL were developed to be straightforward and not require any sophisticated equipment, it is important to keep an eye out for possible sampling errors. The list below summarises some of the key pitfalls and common mischaracterization issues that we have come across in our collective experience of PAWC characterisations across Australia.

To allow interpretation and use of the data by others, PAWC characterisations should be accompanied by as much extra information as possible, including descriptions of the landscape position, surface condition (e.g. cracking, waterlogging), colour, texture (ideally with a full particle size analysis), Australian soil classification and any local classification soil name.

DUL

- Weeds are often seen growing on the side of the plastic cover. It is important that these are strictly controlled throughout the wetting up process until sampling.
- In sandy-textured soils the concentric rings of dripper line must be laid sufficiently close to each other to ensure consistent wetting across the whole area.
- Allowing insufficient time for drainage may lead to overestimation of DUL, especially at depth. Heavier soils can take 1-2 months to drain.
- Insufficient water application or application at too high a rate leads to underestimation of DUL at depth. This is particularly an issue with heavy clay soils, dispersive sodic soils and strong duplex (texture contrast) soils where water may move sideways. Both the GRDC *PAWC booklet* and the *Soil Matters* book provide indicative rates and amounts for different soils. The wetting and drainage processes may be monitored (e.g. using NMM or a moisture probe), but this is not often done due to cost constraints (time, money).
- Bulk density sampling, which is often done in conjunction with DUL sampling, requires a relatively high level of precision as any error in bulk density values will propagate when used to convert gravimetric water contents (including DUL, CLL and PAW) into mm of water. The procedure is described and illustrated in detail in the GRDC *PAWC booklet*.
- Snakes like to hide under the plastic, so take care when wetting and sampling the plot.

CLL

- The CLL method as described above relies on crop roots exploring the soil to the fullest extent. If the crop had insufficient moisture to establish its root system prior to anthesis, the CLL may not reflect maximum soil water extraction. Roots will not grow through a dry layer even if there is moisture underneath. It is, therefore, important to perform CLL measurement in paddocks with a well established and healthy crop. Wetting up of the CLL site prior to the growing season may help, but requires close attention to weeds and to supplying the right amount of nitrogen fertiliser.

- In wetter climates and years with rainfall in the weeks just prior to the erection of rainout shelters at anthesis may refill the PAWC 'bucket'. If the PAWC is large, this may prevent the crop from using all soil water and result in an overestimate of CLL (too wet). Ideally CLL is measured over multiple seasons, but this is rarely done in practice. Calibrated moisture probes can be an effective tool to assess a crop's ability to extract moisture over a range of different seasons.
- The CLL measured for one crop type may not apply to a different crop type, especially where growing season length or susceptibility to subsoil constraints differs. It is possible that long-season varieties may extract water from a greater depth than short season varieties because of more extensive root development, and hence result in different CLL.
- If sampling is not deep enough to capture the full root zone, PAWC will be underestimated. In this case the CLL and DUL do not reach the same value at the bottom of the profile.
- If there is insufficient wetting of the profile prior or during the growing season, the measured CLL may reflect the CLL of a previous crop. If the current crop has a shallower root system this could cause the PAWC to be overestimated. Wetting up of the CLL site prior to the season may help. Taking a soil core when the rainout shelter is installed and comparing values against those determined at the time of final sampling can assist with interpretation of the data.
- Rainout shelters have blown loose or away on occasions, so it is important to secure the sides firmly into the soil.
- For duplex soils located on hills slopes > 3-5% or soils at the break of slope, subsurface lateral flow can cause soil wetting despite the presence of a well constructed rain-out shelter. Keep an eye on late season rainfall and note any unusual wetness in samples collected.
- Sampling after harvest when the soils are dry and hard, or have hard layers can be tricky. Digging a soil pit can be a better alternative than soil coring from the surface in these situations.

General

- Soil variability may mean there is more than one PAWC profile within the paddock. Variability in depth of layers, e.g. texture contrast in duplex soils, can occur over small distances. This makes mixing replicates and selecting a "representative soil" difficult.
- High soil variability can cause the DUL and CLL measurements to effectively be on different soils (even though they are usually only 2-3 m apart). It is essential to measure DUL and CLL on the same soil type. Yield or soil maps may assist in deciding where to sample.

Where to find existing information on PAWC

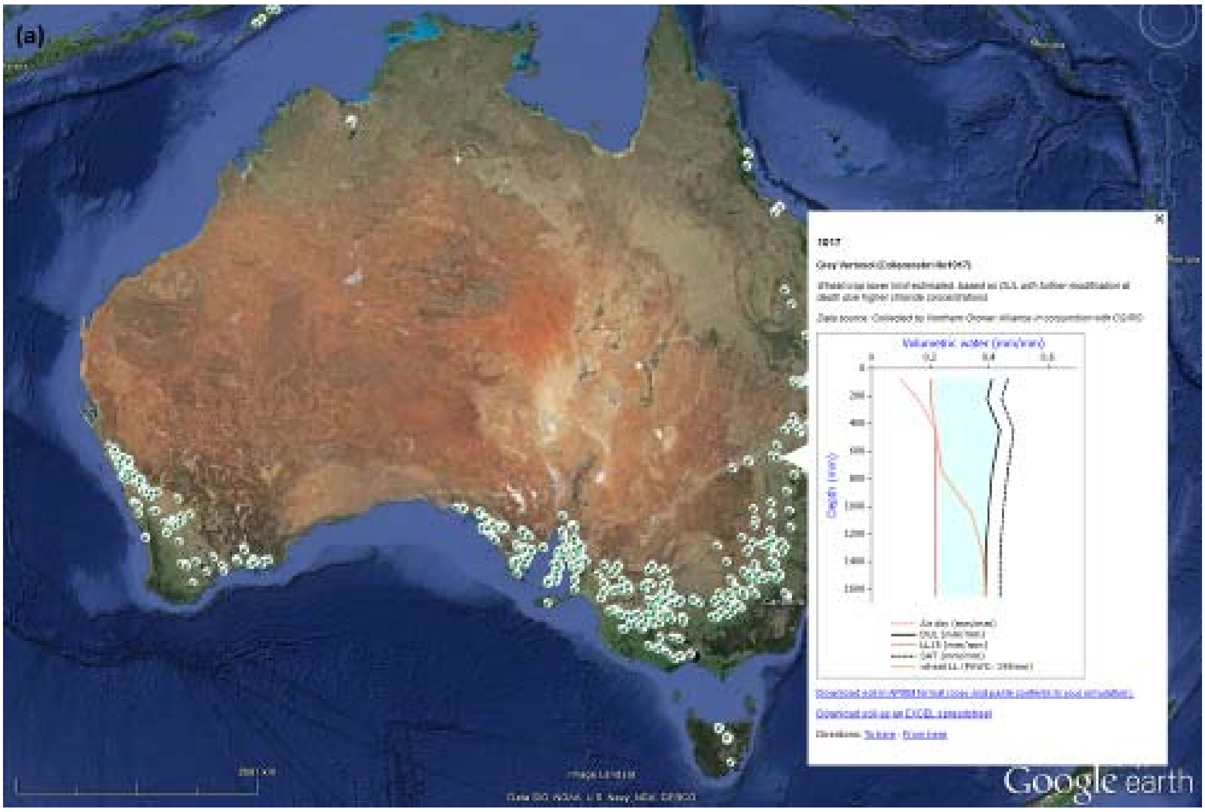
Characterisations of PAWC for more than 1000 soils across Australia have been collated in the APSoil database and are freely available to farmers, advisors and researchers. The database software and data can be downloaded from https://www.apsim.info/Products/APSoil.aspx. The characterisations can also be accessed via Google Earth (KML file from APSoil website) and in SoilMapp, an application for the iPad available from the App store. The yield forecasting tool Yield Prophet® also draws on this database.

In Google Earth the APSoil characterisation sites are marked by a shovel symbol (see Figure 3a), with information about the PAWC profile appearing in a pop-up box if one clicks on the site. The pop-up box also provides links to download the data in APSoil database or spreadsheet format.

In SoilMapp the APSoil sites are represented by green dots (see Figure 3b). Tapping on the map results in a pop-up that allows one to ‘discover’ nearby APSoil sites (tap green arrow) or other soil (survey) characterisations. The discovery screen then shows the PAWC characterisation as well as any other soil physical or chemical analysis data and available descriptive information.

Most of the PAWC data included in the APSoil database has been obtained through the field methodology outlined above, although for some soils estimates have been used for DUL or CLL. Some generic, estimated profiles are also available. While field measured profiles are mostly geo-referenced to the site of measurement (+/- accuracy of GPS unit), generic soils are identified with the nearest, or regional town.

The report *PROFILE descriptions – District guidelines for managing soils in north-west NSW* by Daniells et al. (2002) provides PAWC characterisations for 17 soils in the region drawing on the same methodology. In addition this report provides valuable soil descriptions for areas around Coonabarabran, Coonamble, Moree, Pilliga, and Walgett.



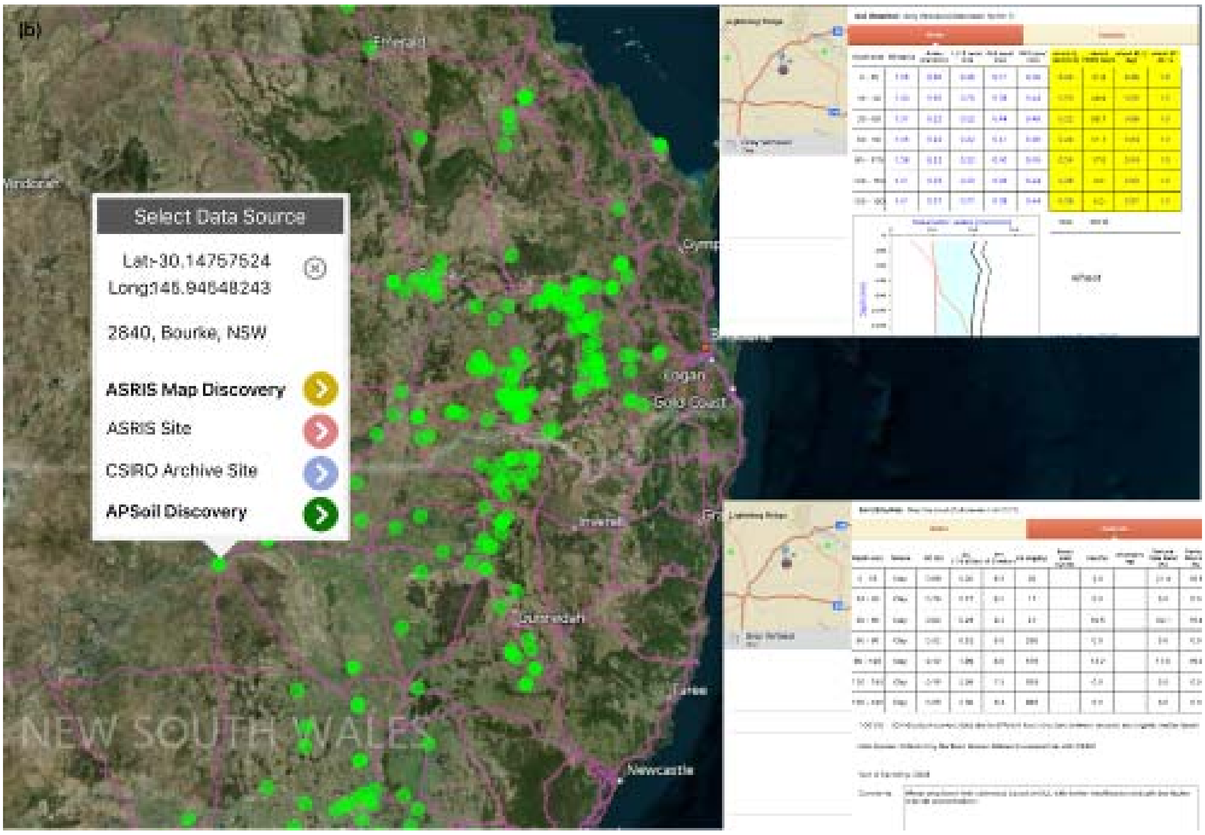


Figure 3. Access to geo-referenced soil PAWC characterisations of the APSoil database via (top) Google Earth and (bottom) SoilMapp (APSoil discovery screens as inserts).

Factors that influence PAWC

An important determinant of the PAWC is the soil's texture. The particle size distribution of sand, silt and clay determines how much water and how tightly it is held. Clay particles are small (< 2 microns in size), but collectively have a larger surface area than sand particles occupying the same volume. This is important because water is held on the surface of soil particles which results in clay soils having the ability to hold more water than a sand. Because the spaces between the soil particles tend to be smaller in clays than in sands, plant roots have more difficulty accessing the space and the more tightly held water. This affects the amount of water a soil can hold against drainage (DUL) as well as how much of the water can be extracted by the crop (CLL).

The effect of texture on PAWC can be seen by comparing some of the APSoil characterisations from the northern region, as illustrated below (Figures 4-8). The soil's structure and its chemistry and mineralogy affect PAWC as well. For example, subsoil sodicity may impede internal drainage and subsoil constraints such as salinity, sodicity, toxicity from aluminium or boron and extremely high density subsoil may limit root exploration, sometimes reducing the PAWC bucket significantly.

The CLL may differ for different crops due to differences in root density, root depth, crop demand and duration of crop growth. Some APSoil characterisations only determined the CLL for a single crop. The CLL for wheat, barley and oats are often considered the same and that of canola can be found to be similar as well, but care needs to be taken with such extrapolations as different tolerances for subsoil constraints can cause variation between crops.

A detailed explanation of the factors influencing PAWC is included in the 'Soil Matters – Monitoring soil water and nutrients in dryland farming' book, a pdf of which is available for free online (see Resources section).

North Star

The available APSoil PAWC characterisations in the region around North Star NSW fall roughly into two groups: lighter, texture contrast soils with smaller PAWC (Figure 4a) and vertosols characterised by larger PAWC, although dependent on texture (Figure 4c and d) and presence of subsoil constraints (Figure 4b, c and d). The PAWC differed depending on crop type due to differing responses to soil chemical conditions and growing season length (Figure 4b, c and d), although where differences are small they could be due to measurement error, including seasonal differences. Soil depth will impact on rooting depth and may also be an important factor determining the magnitude of PAWC, especially on the non-cracking clay soils.

The Profile Descriptions report provides descriptions and PAWC information for soils a bit further south in a region labelled in the report as 'Moree East' around Warialda. It describes the black vertosols that are non-sodic and non-saline as having PAWC up to 265 mm. The non-cracking soils (red and brown) in this area have PAWC between 100 and 215 mm, depending on texture and soil depth.

There are a number of APSoil characterisations to the east of this around the Newell Highway, which show varying PAWC. Factors like soil texture, depth of soil and subsoil constraints would play a role in determining the PAWC profiles, much like the examples shown in Figure 4.

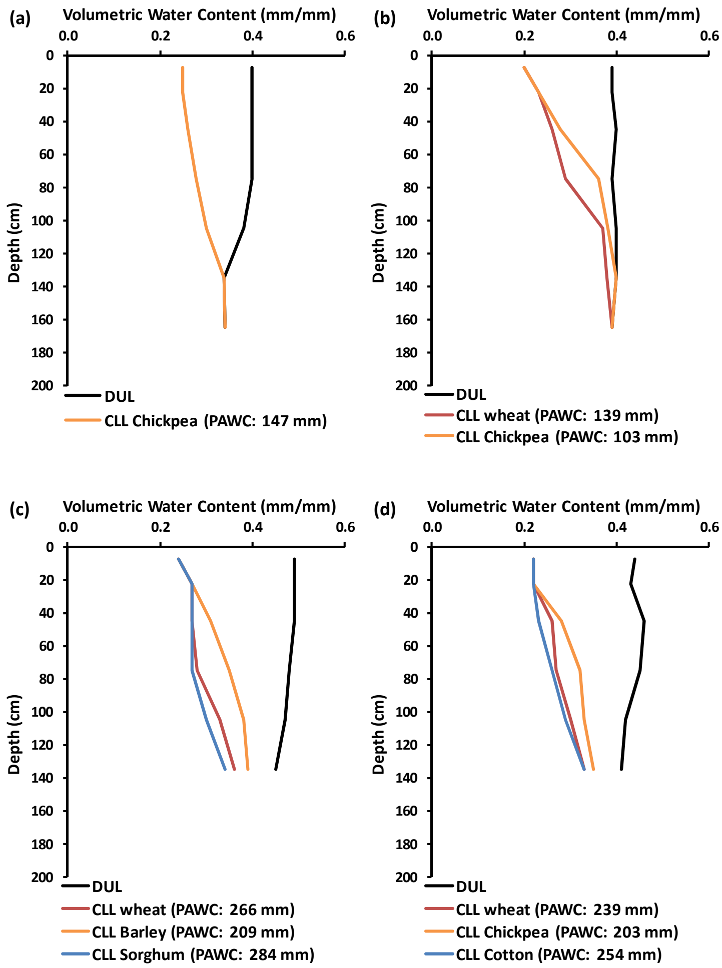


Figure 4. Soils near North Star (see (a), (b), (c) and (d) below:

(a) Red chromosol (texture contrast soil) (APSoil 240) near North Star. The PAWC in the surface soil seems a bit high for a chromosol, which would normally show a shift and widening of the PAWC bucket. It could be that the texture change was not picked up if it was too shallow. Unfortunately particle size information was not available. Depth of texture change and subsoil chemistry will affect PAWC of the texture change soils.

(b) Black Vertosol (APSoil 237) near North Star with subsoil constraints limiting the PAWC (narrowing of the PAWC profile from 60 or 80 cm. Different crops respond differently to the constraints.

(c), (d) Clay content affects the PAWC of the vertosols as illustrated by (c) a Grey Vertosol - heavy Brigalow (Apsoil 101) near Tulloona) and (d) Grey Vertosol – Light Brigalow (APSoil 102) near Tulloona. These two soils were located within the same paddock and descriptions 'heavy' and 'light' may have had local relevance describing a texture difference, but particle size analysis is not available so this could not be confirmed.

Choosing an APSoil characterisation

As shown above, the soil PAWC can vary significantly. How do we choose the most appropriate APSoil characterisation, if we are not in the position to do a local field PAWC characterisation? This is still research in progress, but some guidance can already be provided.

- The nearest APSoil may not be the most appropriate as its soil, parent material and landscape position could be quite different (cf. Figure 4)
- Compare soil with descriptions of the APSoil sites (texture, colour, soil classification, chemical analysis). More recently collected APSoil characterisations include chemical analysis and particle size. As illustrated in Figure 4 both particle size and subsoil constraints strongly affect the PAWC.
- Dig a hole (soil auger, soil core, backhoe trench, roadside bank or cutting); note surface features (cracking, hard setting), subsoil issues (salinity, sodicity, etc), rooting depth. This can assist with APSoil selection as well as adapting an APSoil profile to local conditions (e.g. if depth of texture change or rooting depth is different).
- A measured sowing soil water profile (convert to volumetric) needs to 'fit' between CLL and DUL and can assist with APSoil selection (Figure 1b). If the measured (volumetric) water content profile is below CLL or above DUL then the texture of the soil does not match that of the chosen APSoil.
- Opportunistic CLL (e.g. soil core following a dry finish; convert to volumetric) can be compared with CLL of APSoil characterisations.
- Check for nearby soil survey characterisations (SoilMapp, Espade, Queensland Globe (see Resources section) and local soil reports) to help describe soils.
- Draw on soil-landscape mapping (where available) to find APSoil sites in similar landscape positions (see below).
- Native vegetation is often a useful indicator of soil type too and is indeed often included in information about soil-landscape, land resource area and land systems units.

Using soil –landscape information

In many landscapes the soil properties are tightly linked to a soil's development and position in the landscape and these same aspects underpin the many soil and land resource surveys that have been carried out over the years and that are increasingly becoming available on-line. Many of these present a mapping of so-called soil-landscape units that are based on a combination of geology, landscape features like slope and relief, vegetation and groups of soils. Effectively the distribution of soil types described by these maps and their mapping units descriptions are based on a landscape model or story. These descriptions, where available, can be used to interpret and potentially extrapolate APSoil characterisations.

In parts of NSW these soil-landscape units can be accessed through the ESpade tool (see Resources section), which delineates the units and provides a description and typical soil profiles for each unit (see Figure 5). In parts of Queensland, similar land resource area (LRA) mappings are used as part of land management manuals (see Figure 6). Where this information is available, it may be possible to use it to find an APSoil site in a similar landscape position as a first approximation of PAWC.

The concept of using soil-landscape information to classify and inform soil properties is not new. The Queensland land management manuals accompanying the LRA maps draw on the same concept as do the *Glovebox Guide to Soil of the Macquarie-Bogan Flood Plain* by Hulme (2003) and several *Soil Specific Management Guidelines for Sugarcane Production* in different sugarcane growing areas from northern NSW to northern Queensland (e.g. Wood et al 2003). The availability of these maps on-line makes them more accessible and assists with visualising a location's position in the landscape. Combining these maps with the geo-referenced APSoil PAWC characterisations will increase the value that both resources can provide to farmers and advisors.

Using these resources to inform or even predict PAWC profiles is, however, still research in progress. In particular its predictive power and spatial accuracy still needs to be assessed as well as the required level of soil and landscape information. Not all areas within the northern region are covered by these soil-landscape maps and knowledge of (hydraulic properties of) soils within these areas varies too. Another resource that may proof useful in the future but requires further testing for its use in predicting PAWC profiles, is the new Soil and Landscape Grid of Australia (see Resources section) which provides digital soil and landscape attribute predictions at a spatial resolution of 90 m x 90 m).

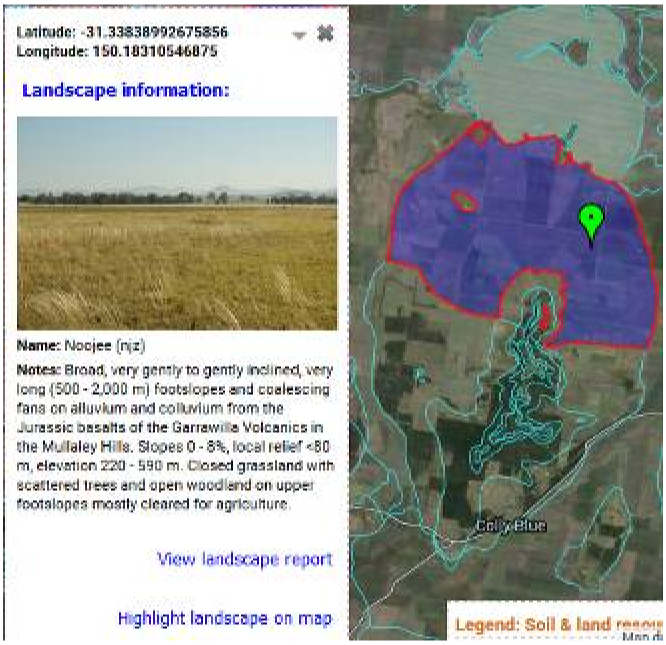


Figure 5. Example of soil-landscape mapping available for parts of NSW through ESpade. Mapping unit description is available through a pdf report and the landscape can be highlighted on the map.

Figure 6. Section of Central Darling Downs with Land Resource Areas (LRA) delineated on Google Earth map with APSoil sites indicated. The accompanying description assisted in explaining the differences between some of the APSoil characterisations.

Local soil and landscape mapping information

North Star

ESpade does not provide on-line access to soil-landscape mapping in this area and neither is land systems mapping available online. SoilMapp provides a broad distinction of where the heavier vertosols and lighter texture change soils may be, but within these there will be local exceptions and variations.

The Profile Descriptions report provides descriptions and PAWC information for soils a bit further south in a region labelled in the report as 'Moree East'.

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. We also gratefully acknowledge the contributions of CSIRO colleagues and many collaborators and farmers to the field PAWC characterisations. Their feedback also helped prepare the list of 'tips and tricks'. The information on PAWC presented in this paper heavily draws on the work over many years by Neal Dalgliesh. Discussions with him and others, including with those involved with soil-landscape mapping in NSW (Neil McKenzie, Rob Banks, Brian Murphy and Neroli Brennan) were invaluable for the development of concepts and ideas presented in this paper. We thank Sean Murphy for access to the Profile Descriptions report for north-west NSW and its authors for the work involved with the PAWC characterisations and soil descriptions. Claire Yung provided assistance with the preparation of graphs.

Resources

APSoil, PAWC methodology and national information

APSoil database: http://www.apsim.info/Products/APSoil.aspx (includes link to Google Earth file)

SoilMapp (soil maps, soil characterisation, archive and APSoil sites): Apple IPad app available from App store; documentation: https://confluence.csiro.au/display/soilmappdoc/SoilMapp+Home

GRDC PAWC booklet: http://www.grdc.com.au/GRDC-Booklet-PlantAvailableWater

Soil Matters book: http://www.apsim.info/Portals/0/APSoil/SoilMatters/pdf/Default.htm

Soil and Landscape Grid of Australia: http://www.csiro.au/soil-and-landscape-grid

Yield Prophet®: http://www.yieldprophet.com.au

NSW

ESpade (soil-landscape and land systems mapping and reports, reports on soil characterisation sites from various surveys): http://www.environment.nsw.gov.au/eSpadeWebApp/

Unpublished soil-landscape maps exist for: Nyngan, Walgett, Narromine, Narrabri, Gilgandra

Soil Profile Descriptions - District guidelines for managing soils in north-west NSW (Daniells et al. 2002)

Queensland

Land Management Manuals: https://publications.qld.gov.au/dataset?q=land+managament+manual

Land Resource Area (LRA) maps: Google Earth files: https://data.qld.gov.au/dataset/land-resource-areas-series or via the Queensland Globe https://www.business.qld.gov.au/business/support-tools-grants/services/mapping-data-imagery/queensland-globe

References

Dalgliesh N (2014) Practical processes for better soil water management. GRDC Update paper. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Practical-processes-for-better-soil-water-management

Daniels I, Manning B, Pearce L (2002) Profile descriptions. District guidelines for managing soils in north-west NSW. NSW Agriculture.

Fritsch S, Wylie P (2015) Managing the yield gap to achieve your yield potential on the western Downs. GRDC Update paper. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-the-yield-gap-to-achieve-your-yield-potential-on-the-western-Downs

Hulme P (2003) Glove-box guide to the soils of the Macquarie – Bogan floodplain, Sustainable Soils Management, Warren.

Routley R (2010) Water use efficiency – Optimizing farming systems performance and balancing fallow length and sowing decisions. GRDC Update paper. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/water-use-efficiency-optimizing-farming-systems-performance-and-balancing-fallow-length-and-sowing-decisions

Whish J (2014) Sorghum yield risk vs starting soil moisture. GRDC Update paper. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Sorghum-yield-risk-vs-starting-soil-moisture

Wood A, Schroeder B, Stewart B (2003) Soil Specific Management Guidelines for Sugarcane Production. CRC for Sustainable Sugar Production, Townsville.

Contact details

Kirsten Verburg
CSIRO Agriculture
Ph: (02) 6246 5954
Email: kirsten.verburg@csiro.au

Brett Cocks
CSIRO Agriculture
Ph: (07) 4688 1580
Email: brett.cocks@csiro.au

Tony Webster
CSIRO Agriculture
Ph: (07) 4059 5002
Email: tony.webster@csiro.au

SoilWaterApp – a new tool to measure and monitor soil water

David Freebairn, University of Southern Queensland

Key words

Soil water, PAWC, soil type, decision making

GRDC code

USQ00014

Take home message

SoilWaterApp (SWApp) provides farmers and advisers with a ready estimate of plant available water in the soil (PAW) during fallows and early crop growth.

SWApp uses weather data from the Bureau of Meteorology that can be localised with manual entry of rainfall or a newly-developed "wireless" rain gauge. Soil types and crops are selected for each paddock.

SWApp is for iPhone and iPad (iOS) devices. Visit www.soilwaterapp.net.au for details.

Background

Grain production in Australia is limited in most seasons by water supply. Soil water stored during the fallow and early season maintains crop water supply leading up to the critical time around anthesis. SWApp has been designed to give grain growers and advisers a simple tool to efficiently and reliably estimate soil water content during a fallow and early crop phases.

The App

The first thing SWApp asks the new user for is a property and paddock name, then by selecting a relevant climate station. Since you are using smart device, it will present you with the 5 nearest available climate stations but you have a choice of 4,500 stations across Australia! SWApp uses long-term records for your site to estimate upcoming rainfall.

A soil type that best represents your soil is then selected from a comprehensive list covering the major soil types in your state. If you want to use more locally relevant rainfall data than the BoM, you have an option to replace the BOM data with records from your rain gauge.

When you "update the site" with the selections listed above, the next screen (below) allows you to: (1) set a start date and soil water distribution; (2) select the soil cover conditions for fallow or crop, and set crop plant and maturity dates; and (3) make additions to a local rain gauge if previously added.

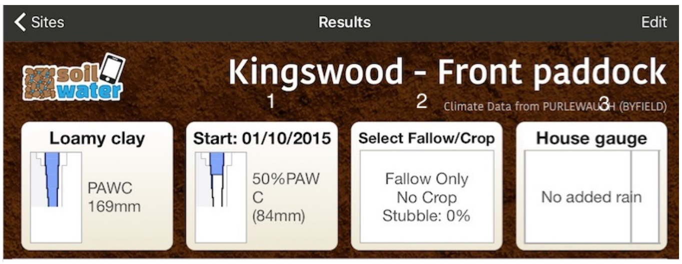


Figure 1. Screen allowing user to (1) set a start date and soil water distribution; (2) select the soil cover conditions for fallow or crop, and set crop plant and maturity dates; and (3) make additions to a local rain gauge if previously added.

Results are shown as text and graphics. Percentage of PAWC and mm water available take centre stage with the water balance and where the water is in the soil profile on either side. The graphic at the bottom of the screen shows the pattern of water accumulation, soil and crop cover. Accumulated rain can be compared with historical patterns as an option.

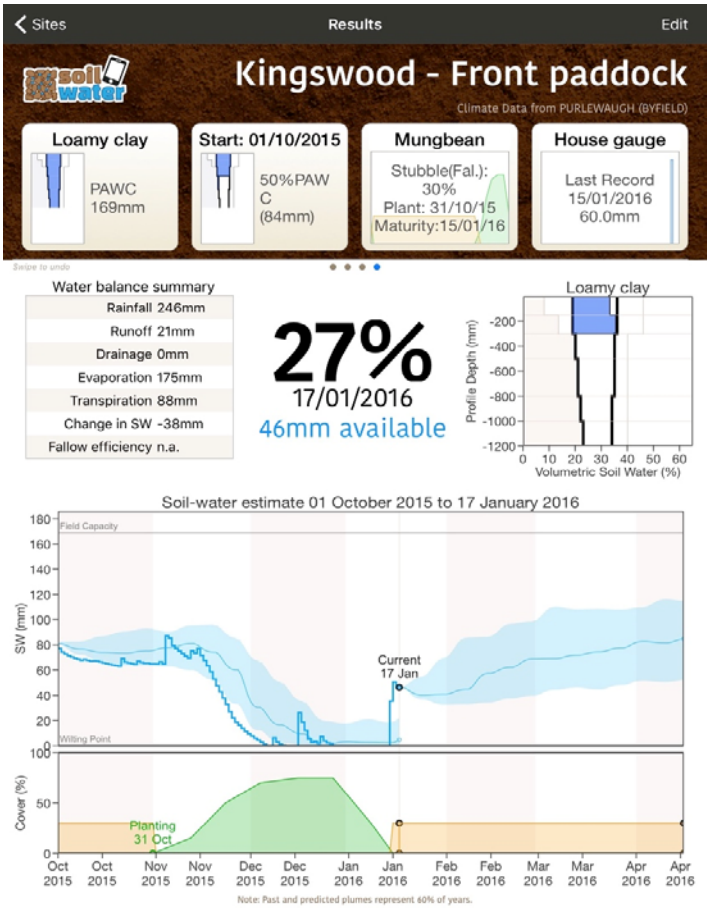


Figure 2. Results screen showing both text and graphics. Percentage of PAWC and mm water available take centre stage with the water balance and where the water is in the soil profile on either side. The graphic at the bottom of the screen shows the pattern of water accumulation, soil and crop cover.

The blue line looking forward from todays date (17 Jan in this example) is based on previous years weather for the specified conditions while the shaded “plume” envelops 60% of likely outcomes.

Data is securely stored and available to multiple devices (other iPhones and iPads). We are currently testing a wireless Bluetooth rain gauge and soil water sensors that SWApp detects and collects data from when your device is nearby (10 metres). Additional facilities such as report generation, a Push Probe data entry and an irrigation module are to be added during 2016.

Acknowledgements

SoilwaterApp was developed for the Grain Research and Development Corporation project “New tools to measure and monitor soil water” (USQ 00014) by the University of Southern Queensland. The project team includes: Prof. Steve Raine, Erik Schmidt, Brett Robinson, Jochen Eberhard, Victor Skowronski, Jasim Uddin and Shree Kodur from USQ and David McClymont from DHM Environmental Software Engineering.

The App’s development has benefited from the significant contributions of grain growers and research scientists across Australia who contributed data for model testing. Valuable feedback from

“beta testers” over the last 12 months has improved the App. We look forward to further constructive comments from users.

Contact details

David Freebairn
University of Southern Queensland
West St, Toowoomba Q 4350
Ph: 040 887 6904
Email: david.freebairn@usq.edu.au

Improving fallow efficiency

David Freebairn, University of Southern Queensland

Key words

Soil water, fallow efficiency, conservation tillage, soil monitoring, Australian CliMate, Soil water App

GRDC code

USQ00014

Take home message

- While ~20% of rain is stored during fallows, small changes in soil management can improve this apparent low efficiency and have large impacts on profit.
- Water stored can be improved through longer fallow, weed control, soil cover and reduced compaction. This can be achieved through reduced tillage, controlled traffic and planting crops before the soil fills.
- Stubble retention combined with reduced or zero tillage almost universally results in better water storage.
- Better water storage results in better yields, especially in dry years.
- Soil water and N mineralisation can be tracked using a number of decision support tools (e.g. Australian CliMate, Soil Water App, Yield Prophet).

Getting water into the soil

Storing soil water is a challenge in our environment where evaporation potential is higher than rainfall in all months. Typically, we have 2-3 times the evaporation potential compared to rainfall. High clay content soils, which hold so much water in the surface, make the value of small falls of rain less useful than we might hope for. High intensity rainfall, a feature of summer rainfall in the northern grain region, can result in valuable water being lost as runoff and resultant erosion.

The starting point for improving rainfall capture is to minimise runoff. Soil cover is a crucial factor determining infiltration (*Table 1*). Cover, either as crop residue or a crop canopy, reduces surface sealing. A puddled crust of 1-2 mm thickness is enough to slow infiltration. On average, a soil cover greater than 40 per cent over the summer can reduce annual runoff by 15-30mm compared to bare fallows.

Table 1. Influence of tillage and soil cover on runoff and water storage on a grey brigalow clay (Greenwood 1978-83).

Tillage management (fallow cover)	Bare fallow (<5%)	Disc tillage (25%)	Blade tillage (45%)	Min/no till (>65%)
Fallow efficiency (%)	21	25	26	32
Range of FE	9-29	8-38	17-36	12-32
Reduced runoff (mm)	-	24	32	15
Extra soil water (mm)	-	13	16	36

Soil cracks also offer a pathway for rapid uptake of rainfall, with intense storms putting some water at depth through cracks, out of evaporations harm's way. Avoid cultivation if soil cover is low and soil is cracked (*Figure 1*).

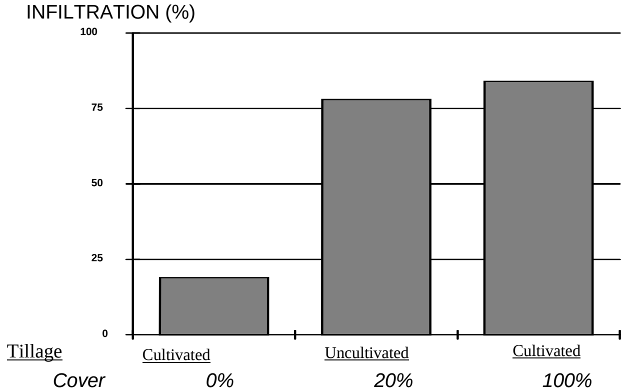


Figure 1. Infiltration of simulated rainfall (40 mm at 100 mm h-1) on a brown clay near Wallumbilla where the soil was cultivated with no soil cover after cultivation, left uncultivated with low cover and cracks, or cultivated with good cover.

Soil water content (How wet?) is important in determining the rate of infiltration. When a soil is full, further rain will either runoff or evaporate. Crop sequences need to be flexible to capitalise on wetter than average conditions and likewise be prudent when soil water is low. As a general rule, fallows longer than one summer are wasteful in terms of storing water. If the soil profile is greater than 50-75 per cent full, planting another crop should be considered.

Keeping it in?

Once rainfall is captured in the soil, the next major challenge is to keep it there for crop use. This is not as easy as it might first seem. During fallows, an average of 65 per cent of rainfall is lost as evaporation - this high loss is largely a result of the high water holding capacity of our clay soils, infrequent rainfall and high evaporation conditions. Many small falls of rain are 'captured' in the top 10 cm, only to be lost to evaporation before the next rainfall.

Stubble can reduce evaporation by increasing the reflectance of the soil surface and reducing the velocity of air movement at the soil surface, but these differences are not long lived. If it stays dry for a few weeks, any gains associated with stubble can be lost. Surface cover and good soil structure allow water to move below the "hot" zone where it will be relatively safe from evaporation "pull". Improvements in water storage have mostly been explained by reductions in runoff losses although evaporation reduction can be important in extending planting dates.

Weeds can be a serious cause of water loss within a crop and fallow - up to 5 mm/day. It is essential that weeds be controlled while they are small to avoid use of soil water and seed setting.

Money in the bank?

Extra water safely stored in the soil through best management can be worth up to 500 kg/ha, especially in dry years. *Figure 2* shows a comparison of grain yields from all tillage trails in southern and central Queensland over a 30-year period. Minimum/no-tillage results in superior yields except in wetter years. In order to make use of available water, nutrition and disease management are equally important, with good rotations a key part of the better water management game. It would be fair to say that farmers have got better at agronomy (compared to researchers) with time than the results in *Figure 2* suggest.

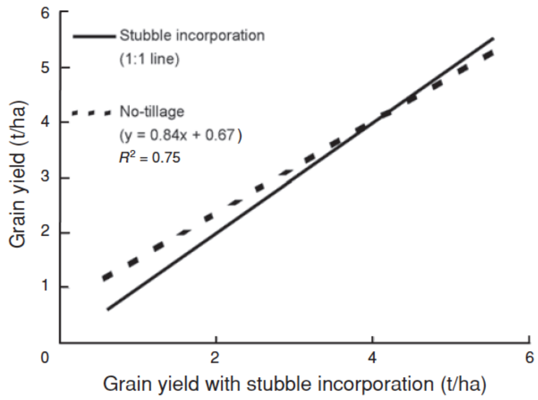


Figure 2. Comparison of grain yields from 120 experiment years from tillage trails in southern and central Queensland in the 1970's to 2007 (Thomas et. al 2007).

Soils are different

While it seems obvious, soils vary greatly, even in the one paddock, so are there any general rules? Much is talked about regarding tillage or no-tillage. Recent research by Dang et al (2014) has shown that an occasional tillage does not appear to undo hard-won gains in soil structure. Some common principles can be summarised as:

- soil cover from stubble or crops is good, and generally the more the better;
- when no soil cover occurs, tillage may be the best option;
- water storage and use is best when crops are growing – provide cover and keep soil drier;
- compaction can only be a bad thing for roots and infiltration; and
- weeds will always be robbers of moisture and nutrients, but may be tolerated at times if small and don't seed.

But each soil needs to be managed differently, and good observation with contrasting management is the best way to learn about your soil. For example, the following observations from a simple rainfall simulation demonstration raised many questions and much discussion (*Figure 3*).

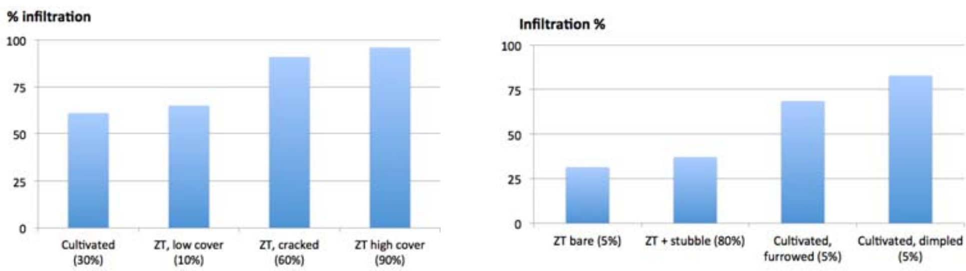


Figure 3. Infiltration of simulated rain on two soil types: a Brigalow-belah clay near Wallumbilla (left) and a red brown earth near Goondiwindi (right) (Cawley et. al 1992).

An example fallow decision pathway

A possible decision pathway for deciding what tillage strategy to follow after harvest.

How long to fallow?

If good rain occurred before harvest, and the soil profile is greater than 3/4 full, extending a fallow is a waste of time, water and money.   Remember that on average, only one mm in every 4-5 mm of rain (20-25 per cent) is stored in the soil. Push probes, soil cores and SoilWaterApp should be sueful here.

Are weeds a problem?

If no, best option is to do nothing. If weed control is necessary, either spray, or cultivate to maximise stubble cover.

Is soil cracked?

- If yes, cracks indicate moisture is gone. Do not cultivate until cracks close.
- Once cracks are closed, either a) maintain stubble cover or b) if little cover, create a rough surface
- Roughness can be created with tillage, but don't use harrows. Extra cover (stubble) cannot be created after harvest so look after it.

What happens if no stubble is available?

Once cracks are closed, tillage is needed to maintained roughness and break crusts. Hard setting soils especially need tillage and roughness (some of these soils may need a pasture phase to improve soil structure).

What happens if the soil is fine and no stubble is available?

An unenviable position - hope for gentle rain and plant a crop as soon as possible.

References

Cawley ST, Hamilton NA, Freebairn DM, Markey LJ, Wockner GH. 1992. Evaluating fallow management options by using rainfall simulation - action learning approach with farmers. QDPI Proj. Rept. SQA 91012. 27 pp.

Dang YP, Seymour NP, Walker SR, Bell MJ, Freebairn DM. 2015. Strategic tillage in no-till farming systems in Australia's northern grains-growing regions: I. Drivers and implementation, Soil Tillage Res.

Thomas GA, Titmarsh GW, Freebairn DM, Radford BJ. 2007. No-tillage and conservation farming practices in grain growing areas of Queensland –a review of 40 years of development. Aust. J. Experimental Agric. 47:887-898.

Acknowledgements

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

Contact details

David Freebairn
Ph: 040 887 6904
Email: david.freebairn@usq.edu.au

Commonly asked questions about soil water and soil management

Graeme Wockner and David Freebairn

Key words

Soil water, soil management, stubble, evaporation, organic matter, infiltration, burning, no till

Stubble factors

Does stubble reduce evaporation?

Yes, in the short term because of reduced soil temperatures but any long-term benefits are negated if we have any hot dry weather after rain. Evaporation is the great equaliser (e.g. 8-12mm free water evaporation a day in summer) which can quickly vaporise any moisture in the surface 0-10cm layer. Stubble is still necessary however, to maintain an open surface structure that reduces the formation of a surface seal and promotes the infiltration of rain.

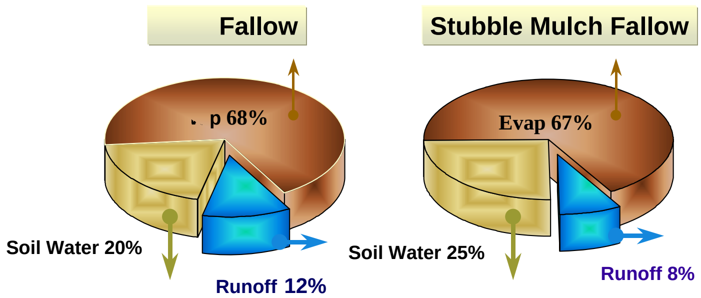


Figure 1. Comparison of two surface management treatments that show only small differences in evaporation but significant differences in soil water infiltration between a bare and a stubble mulch fallow.

Does burying stubble get organic matter into the soil?

Not anymore than leaving it standing. Buried stubble ties up nitrogen in the short term as soil microbes use nitrate for energy to break down the stubble. Above ground, stubble is broken down more slowly by fungi because it is dryer. Eventually the organic matter returns to the ground but in the breakdown process 70% is converted to carbon dioxide.

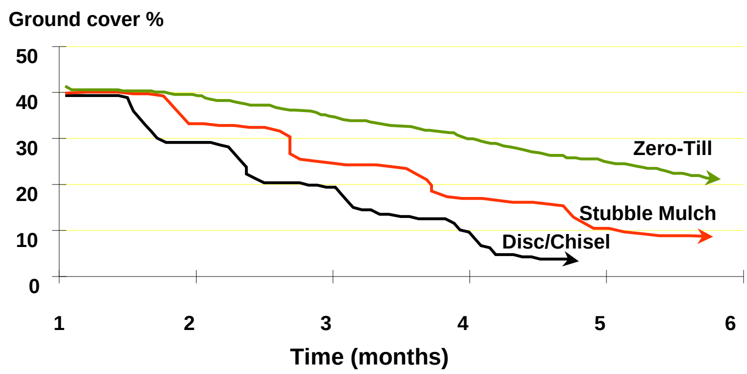


Figure 2. Relationship between time and surface cover breakdown using different tillage instruments

Does burying stubble get more water into the soil than leaving it on the surface?

No, because unless the straw protrudes through the surface infiltration will actually be inhibited. Soil absorbs water like a sponge. You won't improve a sponge by pushing pieces of straw in it! Straw works best by absorbing the energy of raindrops and preventing the surface of the soil from sealing.

Is it better to leave stubble standing or slash it or knock it over?

A catch 22 question because they both have advantages and disadvantages but it is generally accepted that standing stubble is more effective in erosion control. Stubble laying flat increases the overall cover percentage but most high intensity summer storm rainfall falls at an acute angle so standing stubble absorbs a lot of the rainfall energy. Standing stubble is also rooted in the soil and less likely to be washed downhill. Standing stubble is less likely to clog planters in a no-till farming system than slashed or flattened stubble.

Does organic matter improve soil structure and infiltration?

Yes, but we need a lot of organic matter to make a difference. All soils benefit from increased organic matter but unfortunately this is a slow process. It can take less than 20 years to run soils down but much longer to rebuild good soil structure. Organic matter encourages soil fauna; eg: beetles, ants and worms which effectively improve infiltration.

What is the best way to improve organic matter?

Maintaining or improving soil organic fertility through management practices is an important basis for sustainable farming. A decline in organic carbon is accompanied by degradation of a range of properties important for soil fertility. A pasture phase incorporated into your rotation is probably the best way to build organic matter. No-till farming is also beneficial but takes time to substantially raise levels.

Is a late stubble burn OK with regards to soil erosion?

Yes; with the proviso that we delay it as long as possible (e.g. late April). March traditionally has the highest runoff but not the highest rain. This is because the soil moisture profile at this time is nearly filled to capacity and "when a bucket is full", water can only run off. If the rain is intense it will take soil with it. The downside of this is that burning is often a more difficult procedure later in the season. If a clean burn is not possible then the use of fire harrows to substantially reduce stubble levels is recommended. Modern no-till machinery is capable of handling large amounts of stubble that don't require burning.

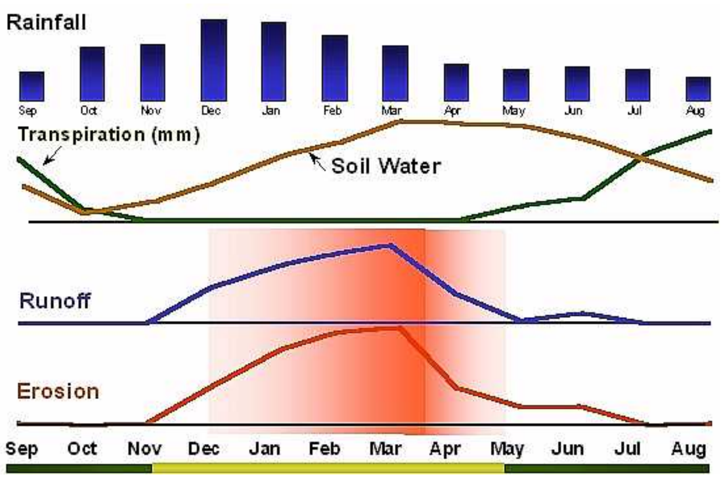


Figure 3. Water dynamics of a summer fallow

Stubble burning is an option available for farmers to control diseases such as yellow spot, minimise nitrogen tie-up in crop residues, and make planting easier with conventional equipment after heavy crops. The 1998 winter wheat crop was severely affected by leaf diseases, and burning was an option for reducing potential carry over of disease. However, in many cases, there is sufficient disease inoculum in the environment to reinfect crops if weather conditions are favourable. Burning a paddock will not remove spores that are present in adjacent grassland for instance.

Bare ground left after burning greatly increases the chance of erosion while reducing the efficiency of water storage during the fallow. If stubble must be burnt, the risk of extreme erosion can be reduced if burning is carried out at an appropriate time. While it is not a prescribed management practice, burning may be practiced from time to time. The key is to understand the risks of runoff and consequent soil erosion.

Other considerations

Will a delay in burning mean it gets too wet to burn!

The risk that a season will turn wet, thus losing an opportunity for a clean burn, needs to be weighed against improved water storage and erosion control. Typically there are many opportunities for a burn through March - April. As a compromise, it may be worth considering burning fewer acres initially.

What if a crop is planted soon after a burn?

If another crop is established quickly, it will provide soil cover, and use soil water (water deficit is the best guarantee for minimising runoff and erosion) thereby minimising the risk of soil erosion.

Will a stubble burn result in less nitrogen tie up?

Generally there is initial less plant available nitrogen when stubble is retained. Over the longer term, losses of organic carbon and nitrogen associated with burning, increased erosion and faster declines in total nitrogen and organic matter in soil eliminate the difference between the two practices.

Will stubble burning reduce disease in other crops?

The main reason to burn is to reduce carry over of yellow spot. Yellow spot mainly affects wheat, so the best strategy to avoid yellow spot is to plant an alternative winter or summer crop in rotation.

Does No-Till promote diseases and pests?

Although some disease organisms grow or survive on stubble, there are strategies to overcome most problems. Rotation of crops is the key. Mice thrive on grain, not stubble - it has too low a feed value, just as it is not preferred by stock. Stubble does provide some protection for mice, but avoiding spilt grain and good farm hygiene are major preventative measures. Complete removal of winter grains can be a challenge in seasons where cereal grains are small or crops lodge.

What can we do when there is no stubble?

Roughness is an option as the increased micro-relief acts as a physical barrier to water movement and increases the entry points for water because of the larger surface area. Results from research work at Wallumbilla show that rough tillage with a chisel plough decreased runoff by 10mm over a summer fallow when compared with smooth scarified tillage.

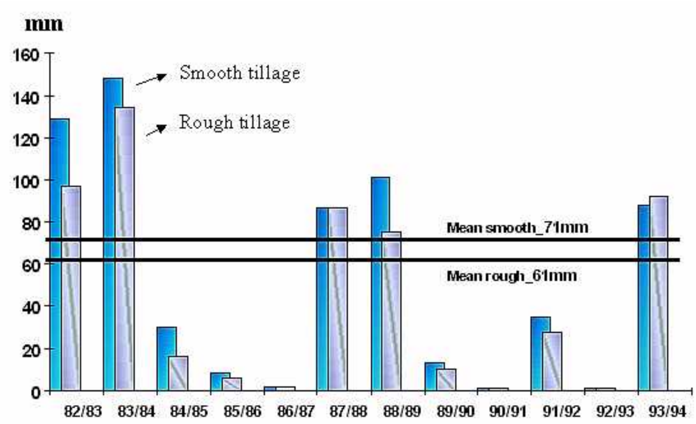


Figure 4. Runoff from smooth and rough tillage treatments at Wallumbilla; Queensland showing the mean 10mm increase in runoff between smooth and rough tillage.

Tillage factors

In controlled traffic can I plough up and down the slope?

Most work in Controlled traffic, which has shown a benefit of up and down working, has been done on fairly low slopes. More work is needed to show the effects on steeper slopes. However, controlled traffic is only successful in reducing erosion in no-till farming systems. In the end, cover is the key to reducing runoff and erosion.

No-till promotes waterlogging and runoff in wet years. Is that so?

Yes and No. Untilled soil with good soil cover increases infiltration and therefore the “bucket” (soil profile) fills sooner. In a wet year because our bucket fills quicker any further rain can only run off or remain on the surface if there is insufficient drainage. Trial work at Greenmount in south-east Queensland has recorded relatively high runoff from no-till treatments sooner in the season than other treatments because the no-till profile filled the quickest. Conversely, in dry years this rapid filling of the bucket gives no-till its big yield advantage.

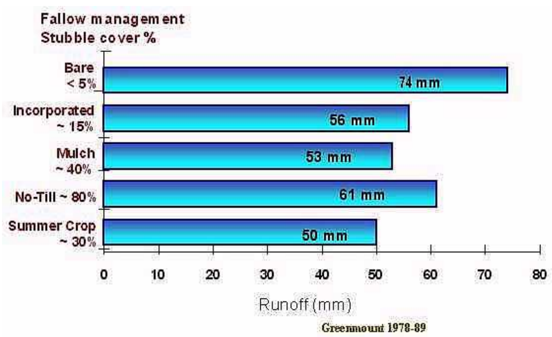


Figure 5. Mean runoff data from Greenmount showing the relatively high runoff from no-till when compared to other treatments.

What effect does herbicide have on worms?

Herbicides (plant killers) should not be confused with insecticides which are sometimes deadly for non-targeted species. The most common herbicides used in no-till systems have no effect on worm populations. Populations of worms in tilled paddocks are usually quite small. Worms and steel ploughs don’t mix.

Is opportunity cropping worth it ?

Generally, Yes, in Queensland's variable climate. Since the 1970's the best farmers have been saying "Use it or lose it" when talking about soil water. However, opportunity cropping means your farming system must be very flexible. E.g. machinery, seed and long or short crop varieties must be available.

How soon do weeds start having a negative effect on stored moisture?

As a rule of thumb if weeds (e.g. summer grasses)have 8 days to establish, they can then grow at 2-3 centimetres a day. Therefore they are depleting our stored reserves (below 10cm) after 12 days.

Rainfall factors

Are weather forecasts based on the SOI too late to make winter cropping decisions?

The SOI forecast for winter is most accurate after late May. Weather experts have to be conservative in their predictions until they know for sure that the pattern has stabilised. If you keep your own records you can observe weather trends, which allow individuals to make earlier decisions. Weather forecast systems are constantly improving and researchers are confident that earlier, more accurate long-term predictions will eventually be possible.

Is rainfall amount a useful measure of how much soil moisture is stored in the fallow?

Not necessarily, it depends on how much rain fell. Steady rain over several days fills the soil bucket. Sporadic light rain (<15mm in a day) will mostly evaporate if dry days follow. Heavy rain (>50mm in a single storm) will produce runoff. Flood rains may only wet a hard setting soil to a few centimetres.

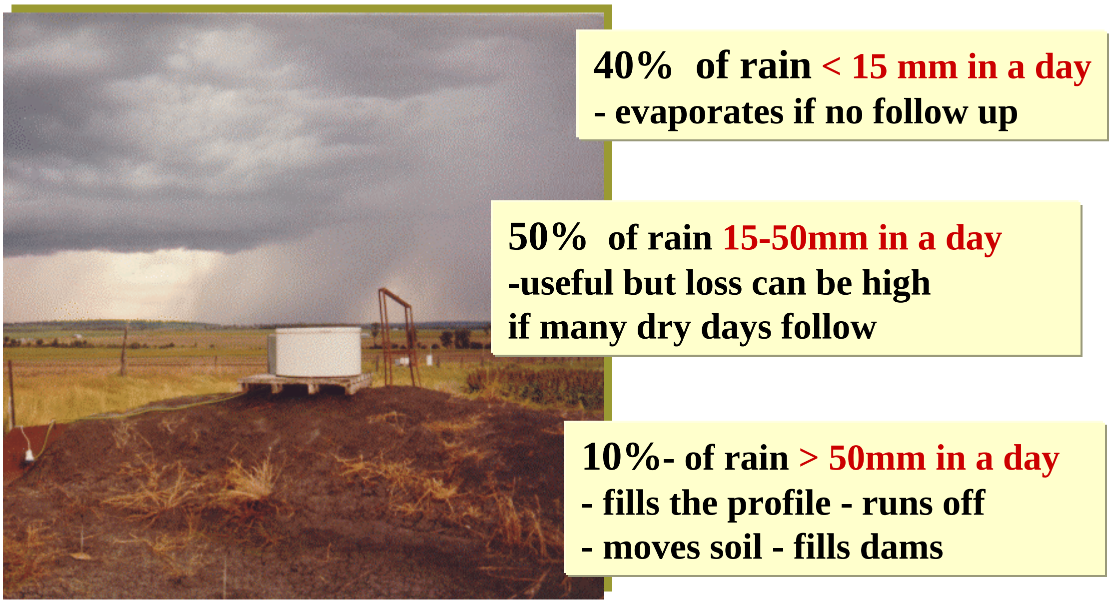


Figure 6. Rainfall fits into different categories

Soil factors

Should nitrogen be applied early or late?

No firm answers because it depends on the season. If we don't have any rain after we apply early we can have losses. (This may be compensated if nitrogen is cheaper earlier in the season.) Early application means one less job at planting but we might just end up fertilising the early weeds! Nitrogen is extremely mobile and a wet fallow can move it deeper into the profile so a small starter application at planting may be necessary. Some experts feel that banding is best as the growing crop has a better chance of competing for the available N. Top dressing before the flag stage is important because the efficiency of N use drops off dramatically.

Do cracks promote evaporation from the sub soil?

Only in negligible amounts. A soil cracks when it is dry so if a soil is cracked the water has already gone. The crack is more likely to be a net receptor of any storm runoff that a net loser through evaporation. There is little sunlight or air movement in a crack and these are the main causes of evaporation.

Why does my lighter country do better than my heavy country sometimes?

Rainfall on lighter soils infiltrates deeper and more evenly than into a heavy clay but a clay soil holds a lot of water in a small volume of soil. A black earth may hold 18mm of rain per 100mm depth of soil. By contrast, a red earth may only hold 10mm per 100mm or 80% less. Therefore a light fall of rain will only wet a shallow depth of a clay soil but will soak down to a greater depth in a lighter textured soil. This means that light falls of rain on clay soils may evaporate more easily because the water is held close to the surface.

Lighter soils hold water less tightly than a clay soil. Plants can more easily soak up water in a light soil whereas some water in clay soils is not available to plants. Clay soils, then, require more rainfall before plants can extract water from them. This means that plants will respond to light falls of rain better in a light soil. Because clay soils store a greater amount of water, they can supply plants with water longer than light soils when droughty conditions follow good soaking rains.

Can cultivation seal in the moisture?

No. Cultivation turns soil over and exposes moist soil underneath to evaporation. Sometimes a cultivated layer “dust mulch” feels dry while the subsoil feels damp. The surface soil is not sealing in the moisture; it is just evaporating to dryness faster than the sub-soil. At night, when evaporation is less, the dust mulch, too will feel moist as water diffuses from the wetter subsurface to the dry surface.

Contact details

Graeme Wockner and David Freebairn,
Previously Queensland Department of Primary Industries, Natural Resources and many other departmental names, First prepared in 2005

David Freebairn
University of Southern Queensland
West St, Toowoomba Q 4350
Ph: 040 887 6904
Email: david.freebairn@usq.edu.au

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

Maurie Street, Grain Orana Alliance

Key words

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

GRDC code

GOA 00001

Take home message

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

Background

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

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

Methods

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

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

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

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

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

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

Coonamble 2009

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

Dubbo 2009

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

Warren (Site 1) 2010

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

Nyngan 2010

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

Warren (Site 2) 2010

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

Nyngan 2011

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

Warren 2011

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

Wongarbon 2011

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

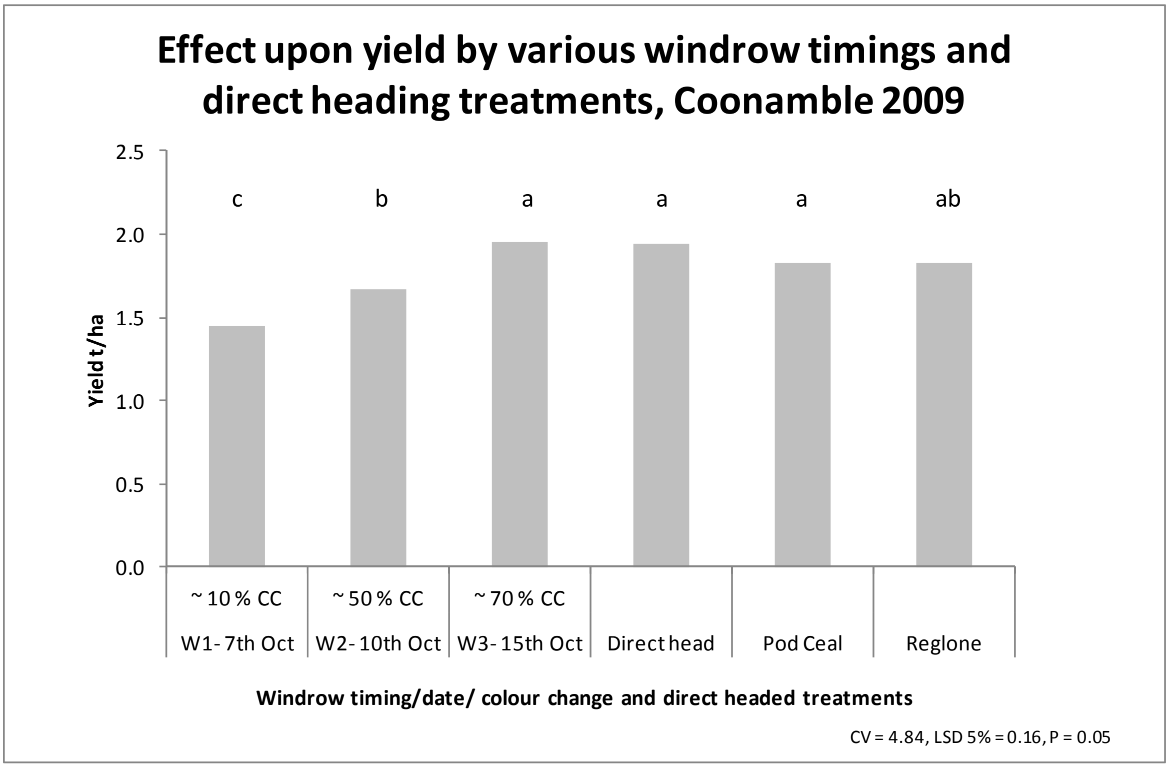
Wellington 2011

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

Results

Coonamble 2009

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

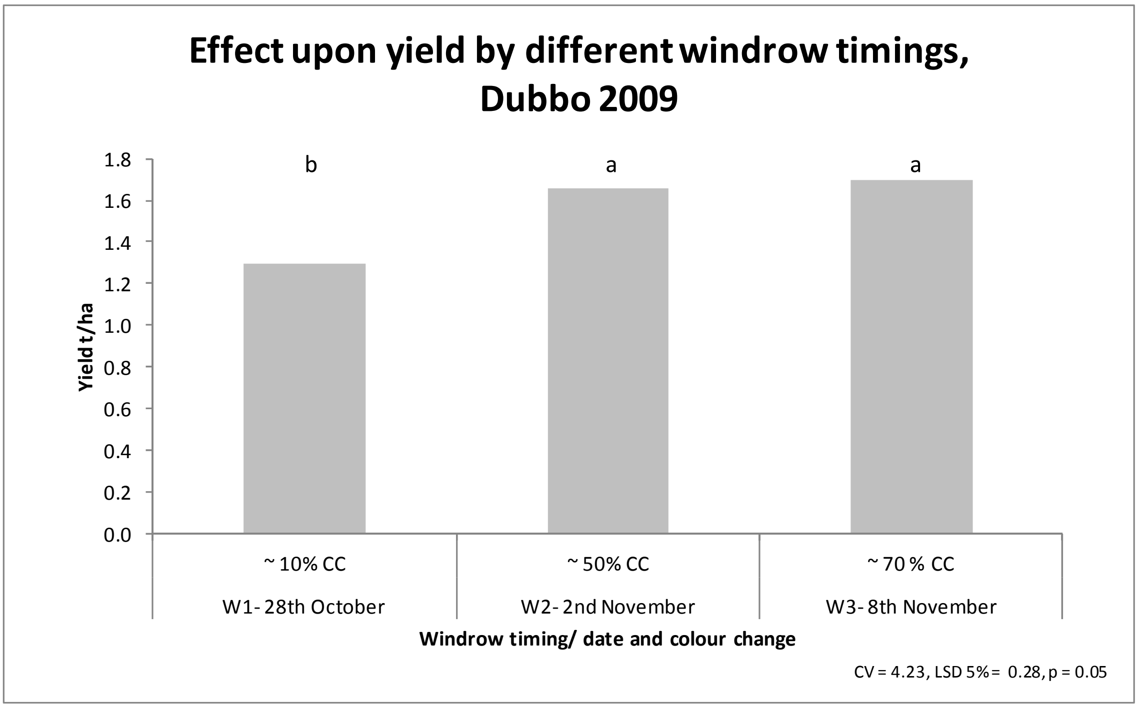


Treatments headed by the same letter denotes no significant difference

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

Dubbo 2009

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

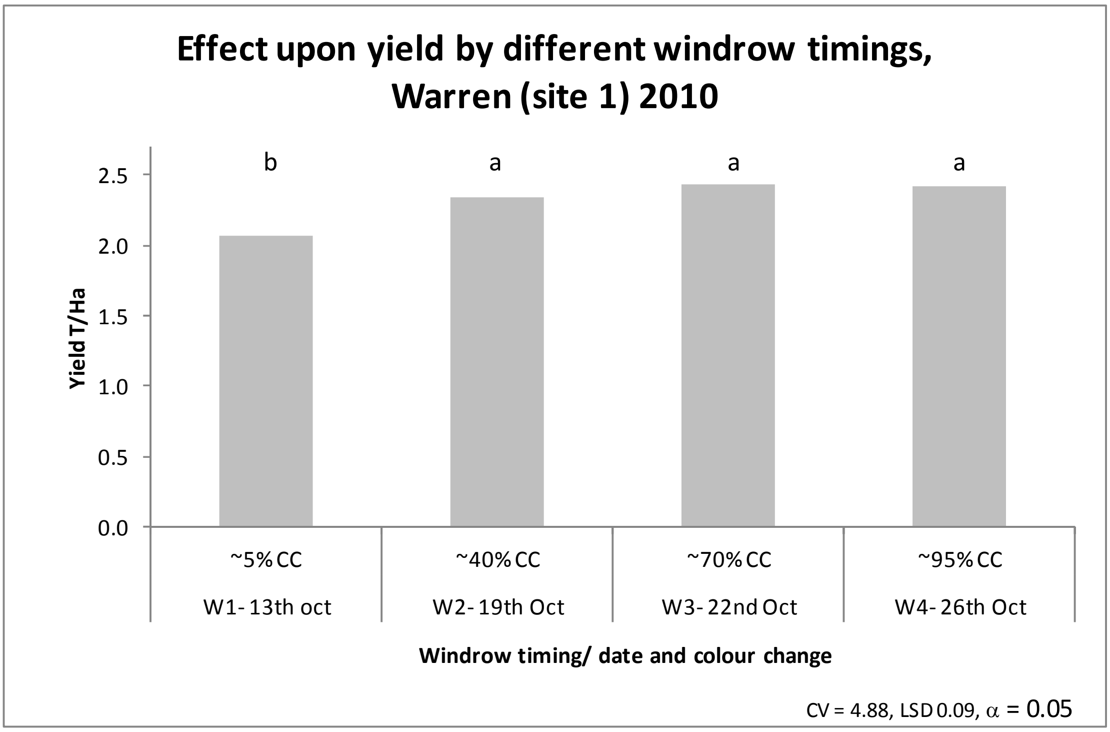


Treatments headed by the same letter denotes no significant difference

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

Warren 2010 (Site 1)

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



Treatments headed by the same letter denotes no significant difference

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

Nyngan 2010- no graph shown

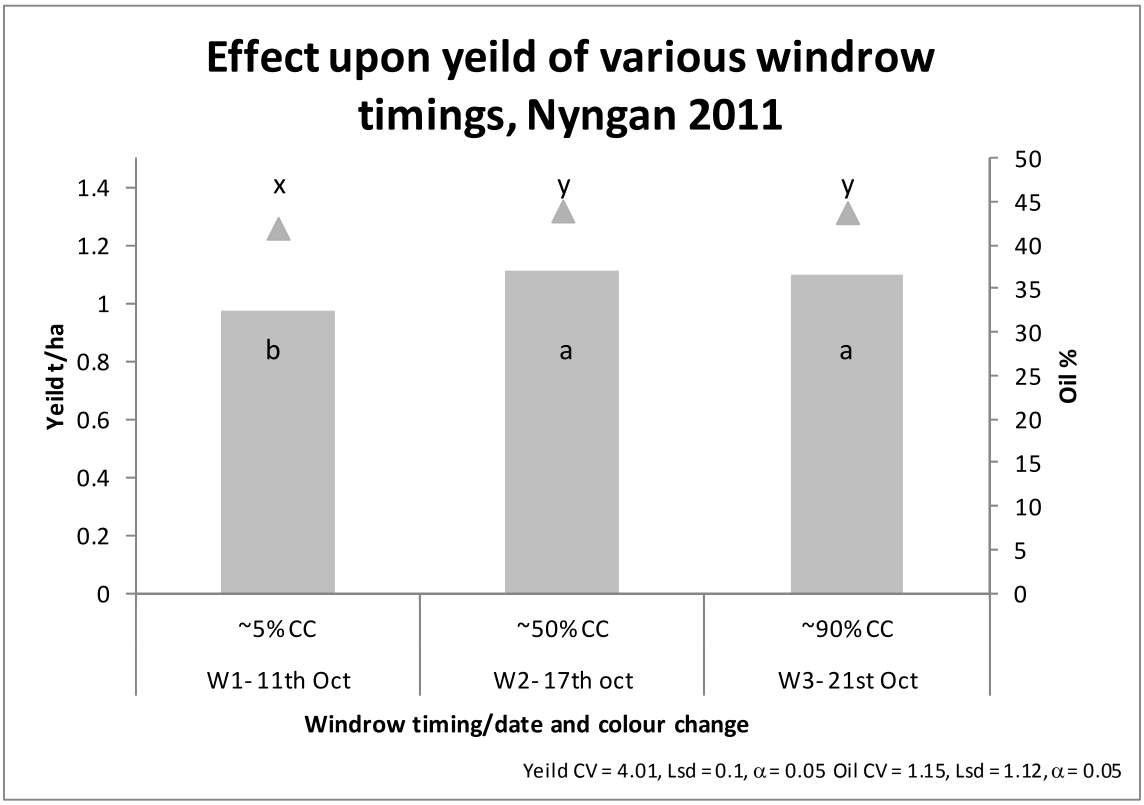
- From a delay in windrow timing from 60% to 90% there was no significant difference in yield or oil%

Warren 2010 (Site 2) - no graph shown

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

Nyngan 2011

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



Treatments headed by the same letter denotes no significant difference

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

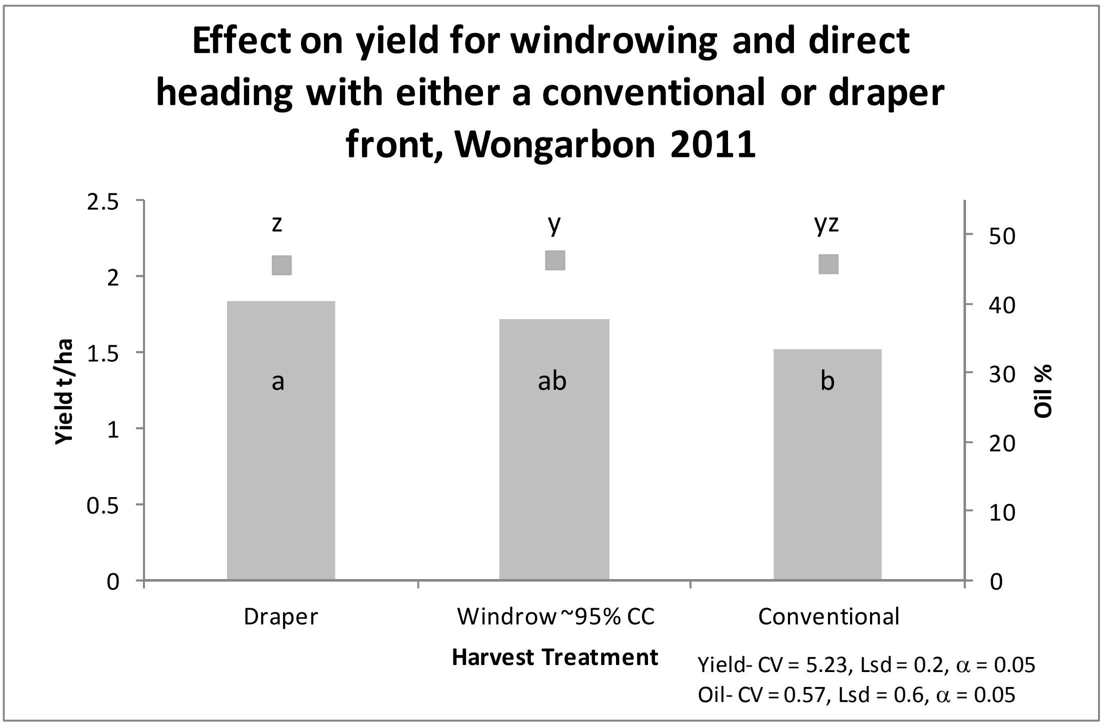
Warren 2011 (no graph)

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

Wongarbon 2011

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

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

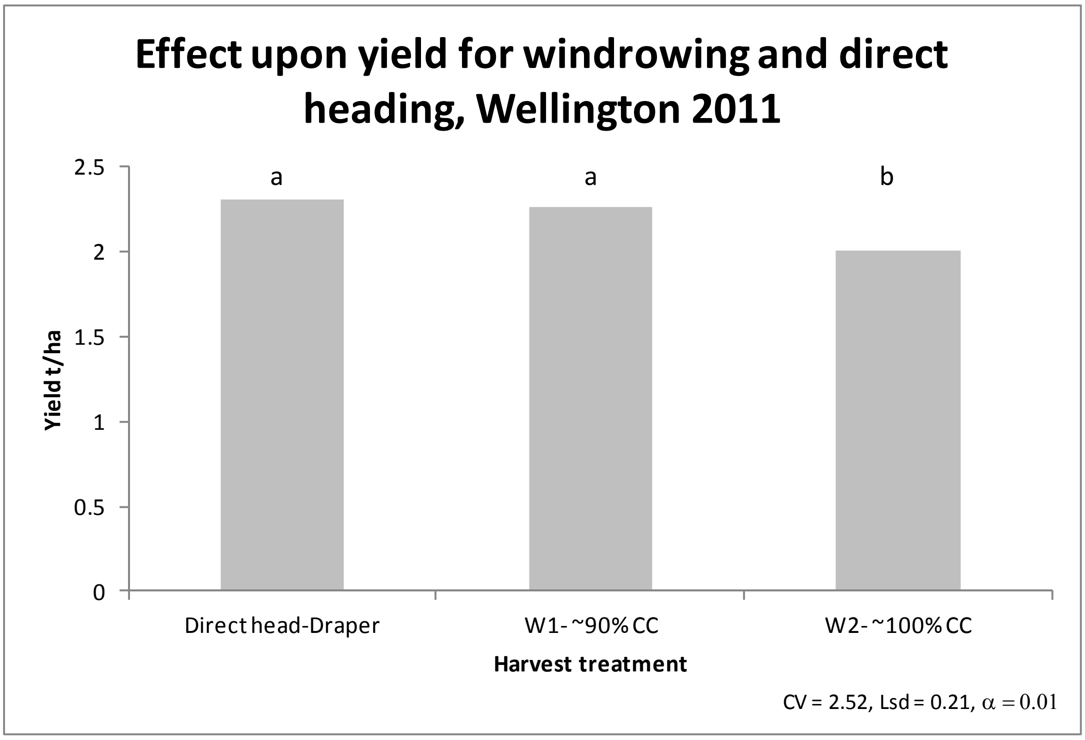


Treatments headed by the same letter denotes no significant difference

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

Wellington 2011

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



Treatments headed by the same letter denotes no significant difference

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

Discussion

Yield

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Oil levels

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

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

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

Assessing crop maturity- is there a better way?

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

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

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

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

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

What is it all worth?

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

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

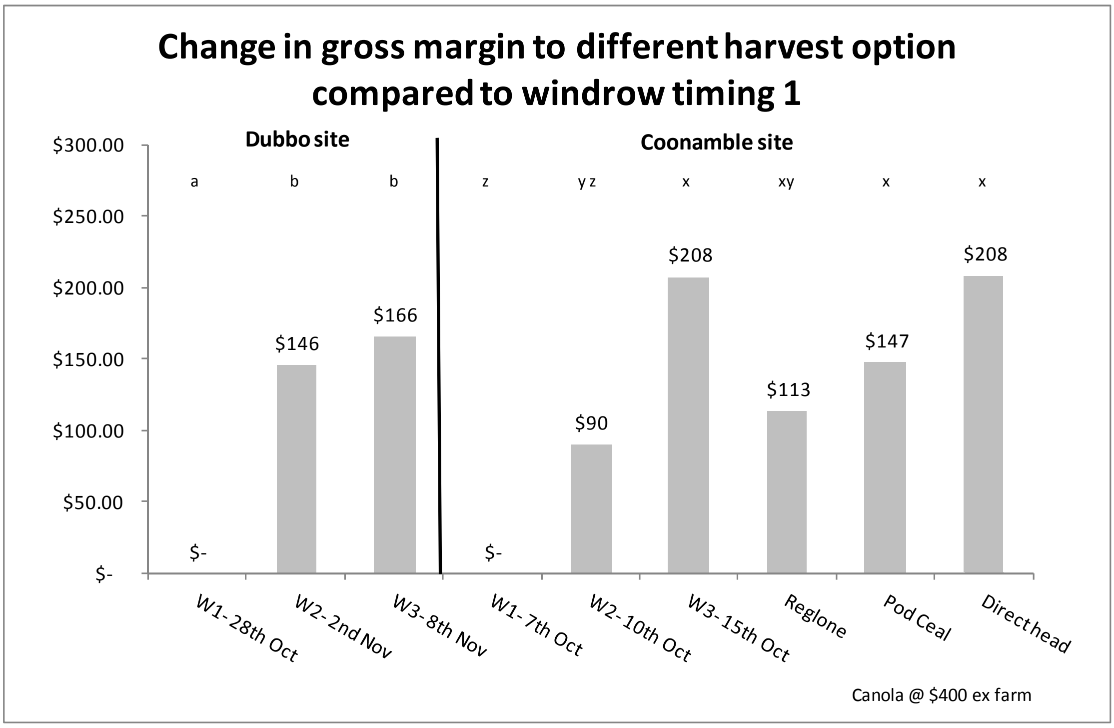
Comparing windrowing to direct heading can be more complicated. There are obvious savings in windrowing costs when direct heading, but the rate of harvesting windrows to direct headed crops can vary. Key considerations may include the width of the windrower swathe compared to that of the header front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

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

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

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

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



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

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

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

Conclusion

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

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

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

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

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

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

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

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

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

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

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

GRDC Direct Heading Fact Sheet: www.grdc.com.au/GRDC-FS-Direct-Heading-Canola

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

Acknowledgements

Special thanks to:

Clyde Agriculture “Netherway” Coonamble,

Graeme Callaghan- Graeme Callaghan & associates, Dubbo

Garry Evans- “Larry’s Plains”, Dubbo

Lindsay Northcott, North-Hill harvesting, Young

Syngenta crop protection, Australia

Agspec, Australia (Pod Ceal™ Distributors)

John DeLyall- Pioneer Hi Bred Australia

“Haddon Rig” Warren

A Walker-“Erlside” Warren

R Ledger “Erlside” Warren

The Waas family at Nyngan

The Street family- Wongarbon trial site

Mason Family, “Spicers Run” Wellington

Michael White and Co. Wellington

Julie Monroe- GOA

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

References

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

Contact details

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

Canola harvest management in northern NSW – Snapshot of results from Year 1

Leigh Jenkins[1], Rick Graham[2], Rohan Brill[3], Rod Bambach[2] and Don McCaffery[4]

[1]NSW DPI, Trangie Agricultural Research Centre
[2]NSW DPI, Tamworth Agricultural Institute
[3]NSW DPI, Wagga Wagga Agricultural Institute
[4]NSW DPI, Orange

Key words

Canola, harvest management, windrow, Reglone, Weedmaster DST, seed colour change

GRDC code

Optimised Canola Profitability – CSP10087

Take home message

There were negative effects on either yield or oil even at the 50% target SCC timing at both Tamworth and Trangie in 2015. This may have been expected at Tamworth as Hyola 575 CL was only at 27% SCC at the time. At Trangie, there was a yield reduction (at the 45 plants/m^2 density) in both Hyola 575 CL and 44Y89 CL when their actual SCC (averaged across the plant) was beyond 50%. This may have been due to the method of measuring SCC, as the branches were much slower to mature than the main stems. This data suggests that seed colour change should be measured on a whole plant basis, not just on a main stem basis. More attention should be given to branches where they are likely to contribute to a large proportion of grain yield. These experiments will be repeated in 2016 to validate or challenge the one year findings of 2015.

Introduction

Windrowing has been a traditional and common practice for harvest management of canola in Australia. There have been two main reasons for this:

- To reduce shattering losses incurred from storm and wind damage in ripe standing crops and/or during the harvest operation.
- To 'even up' and accelerate the grain ripening process, which can widen harvest windows and improve logistics.

Recently, late non-selective weed control has also been implemented with the windrowing operation.

Industry guidelines say that canola is ready to windrow when 40-60% of seeds on the primary stem have changed colour from green to red, brown or black, which is when seed moisture content is in the range 35-45%.

Research commenced in 2015 as a component of the GRDC co-funded project 'Optimised Canola Profitability', to determine the relationship between seed colour change and grain yield and oil concentration. This will ultimately help growers make sound decisions on canola harvest management across the northern region and potentially across Australia.

2015 experiments

In 2015, experiments were conducted at Trangie Agricultural Research Centre and Tamworth Agricultural Institute. Factors affecting grain yield and oil concentration were examined, including variety choice, harvest treatments/products, treatment timing and plant density (Table 1). At each of the 'timings' the treatments consisted of a hand cut for yield for the Windrow treatment, spraying Reglone followed by a hand cut when ripe for the 'Reglone' treatment, and spraying Weedmaster DST followed by a hand cut when ripe for the 'Weedmaster DST' treatment. The experiments were sown in early May and were managed for maximum grain yield potential.

For consistency across these experiments, seed colour change was determined as when a minimum 2/3 of an individual seed surface area had changed colour from green to brown/red/black.

Table 1. Factors included in experiments at Trangie and Tamworth in 2015 to determine canola harvest management effects on grain yield and oil concentration.

Variety	Treatment	Timing (% seed colour change)*	Plant density*
Hyola 575 CL	Windrow	25	15 plants/m^2
44Y89 CL	Reglone @ 2.5 L/ha	50	45 plants/m^2
	Weedmaster DST @ 4.1 L/ha	75	
		100	

*Plant density treatments were only included at Trangie; Seed colour change timings were target only

Results

Within each trial, the two varieties commenced flowering on the same date but there were differences in how the varieties progressed from flowering to maturity. 44Y89 CL was quicker to mature (as would be assumed by its maturity rating) than Hyola 575 CL. This meant that seed colour change (SCC) was more advanced in 44Y89 CL than in Hyola 575 CL for any given 'target' seed colour change timing (Table 2).

Table 2. Actual seed colour change (average of branch and stem at a target density of 45 plants/m^2) compared with target seed colour change for 44Y89 CL and Hyola 575 CL and date of harvest treatment application at Tamworth and Trangie in 2015.

	Tamworth			Trangie		
	44Y89 CL	**Hyola 575 CL**		**44Y89 CL**	**Hyola 575 CL**	
Target	*Actual*		*Date*	*Actual*		*Date*
25	13	8	16-Oct	55	32	9-Oct
50	82	27	27-Oct	91	67	12-Oct
75	93	62	30-Oct	97	78	15-Oct
100	100	91	12-Nov	100	99	20-Oct

There was no significant effect of the application of Weedmaster DST on grain yield or oil at any of the application timings at either location. This supports label recommendations that state 'apply when a minimum of 20% of canola seeds as a random visual sample from various heights in the crop canopy from the main stem has changed to a dark brown/black colour'.

Tamworth

At Tamworth, both windrow and Reglone at the 25% target SCC timing significantly reduced grain yield of both varieties compared with the 100% SCC (Figure 1), although the Reglone treatment was higher yielding than the windrow treatment for both varieties. Despite the 'actual' seed colour change of Hyola 575 CL being less than 44Y89 CL, the response to the treatments and timings of the two varieties was similar. The cause of the grain yield reduction was a reduction in individual seed size.

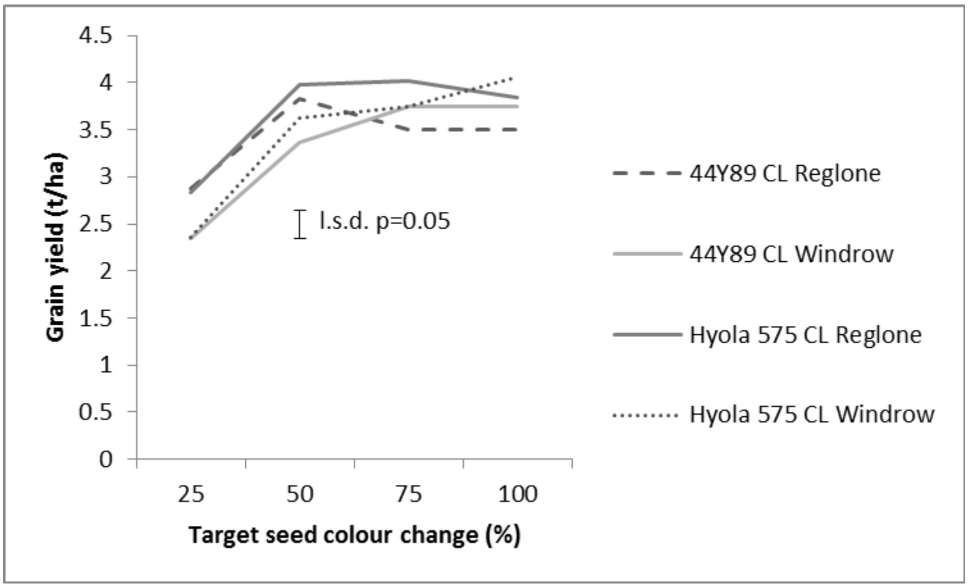


Figure 1. Grain yield of two canola varieties with two harvest management treatments (Reglone and Windrow) applied at four target seed colour change timings at Tamworth in 2015.

For Hyola 575 CL, oil was reduced from windrowing at 25% and 50% target SCC treatments compared with 100% SCC (Figure 2). Reglone did not reduce oil to the same extent as did windrowing. For 44Y89 CL, oil was reduced from the Windrow 25% SCC treatment compared with the 100% SCC, but there was no further oil increase after 25% SCC. The greater reduction in oil concentration of Hyola 575 CL from the early windrowing compared with 44Y89 CL was due to the later maturity of Hyola 575 CL. Actual seed colour change of Hyola 575 CL was 8% and 27% for the first two target timings respectively, compared with 44Y89 CL which was 13% and 82%.

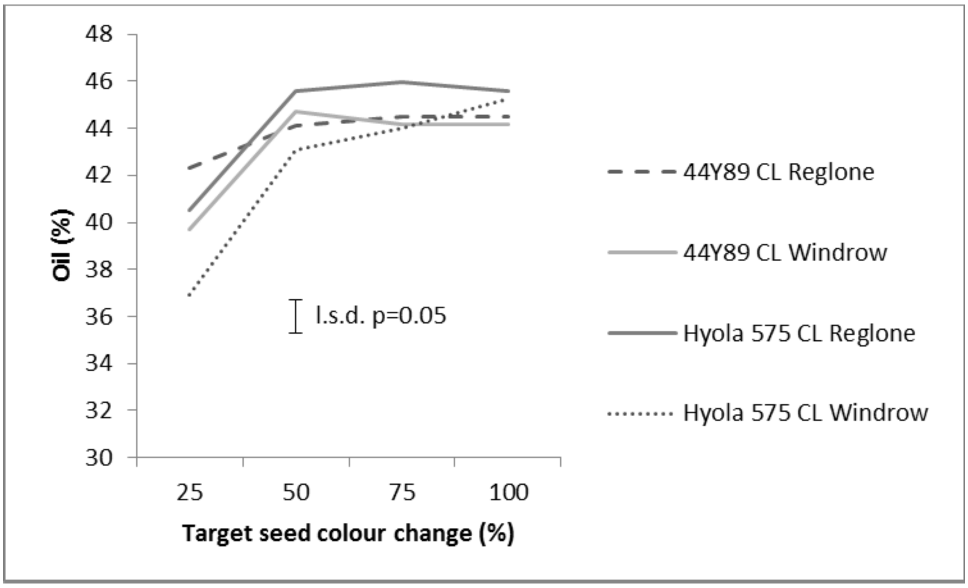


Figure 2. Oil concentration of two canola varieties with two harvest management treatments (Reglone and Windrow) applied at four target seed colour change timings at Tamworth in 2015.

Trangie

To be comparable with the Tamworth experiment, the grain yield and oil results for Trangie are for the 45 plants/m^2 density only. The only treatment to affect grain yield at Trangie was the windrow treatment (Figure 3). 44Y89 CL was higher yielding than Hyola 575 CL regardless of windrowing date. The 25% target SCC (actual 55%) treatment reduced grain yield of 44Y89 CL, compared with the 100% target SCC, but windrowing 44Y89 CL at 50% target SCC (actual 91%) did not reduce grain yield compared with 100% SCC. Grain yield of Hyola 575 CL was reduced, at both 25% target SCC (actual 32%) and 50% target SCC (actual 67%) compared with 100% SCC. Similar to Tamworth, the reason for the grain yield reduction from early windrowing was from reduced seed size.

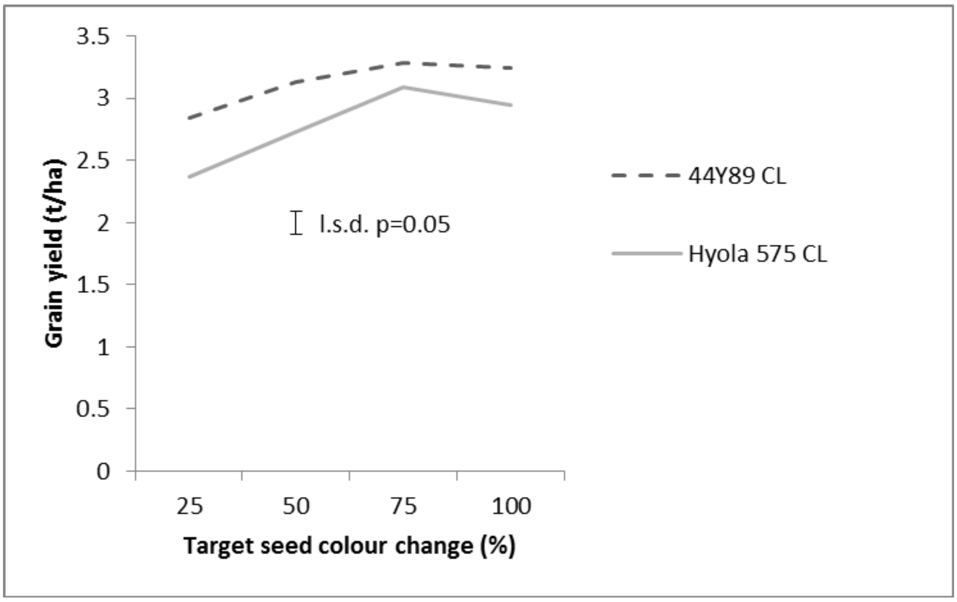


Figure 3. Grain yield of two canola varieties as affected by windrow timing at four target seed colour change timings at Trangie in 2015.

There was a small but significant effect on oil concentration for 44Y89 CL at the 25% SCC timing, with oil reduced by 1.2% compared with 100% SCC (Figure 4). The decrease in oil from windrowing at 25% SCC was stronger on Hyola 575 CL, with a 2.3% reduction compared with 100% SCC.

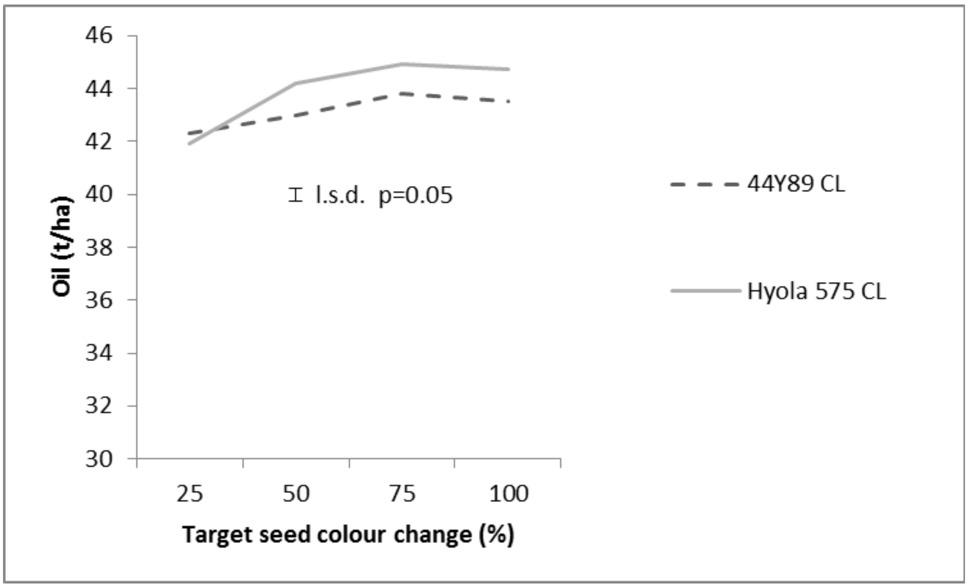


Figure 4. Oil concentration of two canola varieties as affected by windrowing at four target seed colour change timings at Trangie in 2015.

Interpreting seed colour change

At Trangie there was also a low density treatment targeting 15 plants/m^2. The effect of plant density on SCC was less pronounced than expected. For both varieties, the low density had a higher proportion of SCC at the 25% SCC timing. From the 50% SCC timing and later, the higher density had more rapid SCC.

There were larger effects of where on the plant (branch or main stem) SCC was measured. Seed colour change was slower to progress on the branches than the main stem. For 44Y89 CL at the 25% SCC treatment the 'average' SCC of the branch and stem was 55% (Table 3), which on past guidelines would be late enough to windrow. The SCC on the branches was only 44% which would be deemed too early for windrowing. These initial findings suggest that SCC assessments should be made across the whole plant rather than the main stem only. The proportion of grain yield derived from the main stem and the branches has been collected but full data is not yet available.

Table 3. Actual seed colour change on branches and main stems at four target seed colour change timings at Trangie in 2015.

Variety	Component	25% SCC	50% SCC	75% SCC	100% SCC
44Y89 CL	Stem	65	96	100	100
44Y89 CL	Branch	44	86	93	99
44Y89 CL	Average	55	91	97	100
Hyola 575 CL	Stem	39	84	98	100
Hyola 575 CL	Branch	24	50	58	96
Hyola 575 CL	Average	32	67	78	98

Summary

There were negative effects on either yield or oil even at the 50% target SCC timing at both Tamworth and Trangie in 2015. This may have been expected at Tamworth as Hyola 575 CL was only at 27% SCC at the time. At Trangie, there was a yield reduction (at the 45 plants/m^2 density) in both Hyola 575 CL and 44Y89 CL when their actual SCC (averaged across the plant) was beyond 50%. This may have been due to the method of measuring SCC, as the branches were much slower to mature than the main stems. This data suggests that seed colour change should be measured on a whole plant basis, not just on a main stem basis. More attention should be given to branches where they are likely to contribute to a large proportion of grain yield. These experiments will be repeated in 2016 to validate or challenge the one year findings of 2015.

Acknowledgements

We gratefully acknowledge the assistance of technical staff with this work, including Steve Morphett and Jan Hosking (Tamworth); Jayne Jenkins, Scott Richards, Liz Jenkins and Joanna Wallace (Trangie).

Contact details

Rohan Brill
NSW Department of Primary Industries, Wagga Wagga
Email: rohan.brill@dpi.nsw.gov.au

Faba bean agronomy – ideal row spacing and time of sowing

Rebecca Raymond[3], Kerry McKenzie[1], RCN Rachaputi[2]

[1] Department of Agriculture and Fisheries, Tor St Toowoomba
[2] QAFFI, Kingaroy
[3] Department of Agriculture and Fisheries, Goondiwindi

Key words

faba bean agronomy, row spacing, plant population, time of planting, sowing,

GRDC code

UQ00067

Take home message

Changes in agronomy can affect yield of pulses.

In general increasing row spacing may decrease yield in faba bean varieties

A linear reduction in yield of faba beans can occur if sowed after late April however increase in harvest index was found

Background and aims

Despite the potential environmental and economic benefits, the adoption of winter pulse crops in the Queensland Grains Region is around 20% of total cropping area. To increase the share of pulses in the total cropping area, strategies are required to enable growers to more consistently realise the potential productivity and profitability of pulse cultivars in their farming systems.

Winter pulses (chickpea and fababean) currently comprise approximately 20% of total cropped area in the Queensland Grains Region although the adoption varies depending on the growing region and of course price, this has risen from around 8% since the start of the project. Chickpea (*Cicer arietinum*) is the most adapted winter pulse crop in the Queensland with the area expanding to historically high levels in 2010. Seasonal yields of chickpea ranged from 0.5t/ha to 2t/ha depending on the timing and severity of biotic and abiotic stresses during the growing season. Although yields as high as 2.5t/ha have been achieved in varietal evaluation trials, the average yield during the 2008 – 2011 was approximately 1.2t/ha in the focus regions included in this project (Source: ABS statistics), suggesting a significant potential to increase productivity. However, pulse agronomy trials in SQ have consistently demonstrated an increase in harvestable yield by 20- 60% depending on the seasonal conditions, through reducing row spacing. A modest 10% increase in yield would result in a $20 to $25 increase in gross margin (based on a $200/ha gross margin). Over a winter pulse area of 125,000 ha, the increase in crop production would be valued at $2.5 to $3 million per annum.

Fababean (*Vicia faba*) is gaining popularity in the northern grains region thanks to higher prices in recent seasons and improved varieties. Although southern regions dominate the production for Australia; Northern NSW and Southern Qld are looking more favourably upon faba bean as part of their rotation as a break crop for disease and for its nitrogen fixing ability. Yield of faba beans ranges from 2-4t/ha however the pulse agronomy trials have shown a potential of up to 5.5t/ha.

Although the area sown to winter pulses in Queensland has increased over the last three years, there have been many challenges for growers with erratic seasonal conditions and a range of disease pressures on yield and quality. Growers' attitude to pulse crops is also influenced by forecast prices relative to other cropping options including cotton and experiences from the previous season. The area of winter pulses in the region needs to be stabilised and the reliability of achieving seasonal yield potential improved.

The Pulse Agronomy project has consulted widely within the pulse industry to determine the priorities to be investigated throughout the term of the project.

There have been two seasons of faba bean trials at the Garah site as part of the Northern Pulse Agronomy Project; the 2014 season saw the planting of three cultivars PBA Warda, PBA Nasma and Cairo on one planting density of 25p/m^2 and on varying row spacings (25, 50, 75, 100cm). This season saw significant effects of the agronomic treatments observed with varieties responding positively to decreasing row spacing. In addition, 2014 (Dalby) showed a linear reduction in yields after the sowing date of April 23rd.

Winter 2015 saw the inclusion of varied planting densities (5, 10, 20, 30p/m^2) across the same 4 row spacings (25, 50, 75, 100cm) looking at 2 cultivars PBA Warda and PBA Nasma.

A seed size trial was also conducted at a Dalby site which had 3 different seed sizes of the PBA Nasma (IX220-D) cultivar planted at 75cm row spacing at 4 different planting densities. This trial was designed to determine the effects of seed size on yields and whether it is possible to grow a larger proportion of large seeds from smaller parent seeds as there is potential for issues with the larger faba bean seed blocking air seeders.

Time of sowing trials were also conducted at both Warra and Hermitage Research Station in 2015, each site sowing on three dates starting in April and concluding in late May. The initial plan was to begin these sowing dates in late March however rain forced the delay of sowing at both locations. These trials were at varying targeted plant densities on 75cm row spacing.

Results

Row spacing effects on yield

Overall, average yields were obtained at the Garah site and significant effects of the agronomic treatments were obtained. There was deemed to be no significant difference overall between the cultivars PBA Warda and PBA Nasma however PBA Nasma had an overall higher yield at 3.24t/ha over PBA Warda at 2.97t/ha (***table 1***). These results are consistent with those found in 2014 at the same site.

Table 1. Effect of cultivar on yield, Garah 2015 (LSD = 0.321)

Cultivar	**Grain yield (t/ha)**
PBA Warda	2.97a
PBA Nasma	3.24a

The narrower row spacings of 0.25m and 0.5m have significantly out yielded the wider spacings of 0.75m and 1.00m in both 2014 and 2015.

Table 2. Effect of row spacing on yield, Garah 2015 (LSD = 0.454)

Row Spacing	0.25	0.5	0.75	1.0
Mean Yield (t/ha)	3.43a	3.49a	3.18b	2.33c

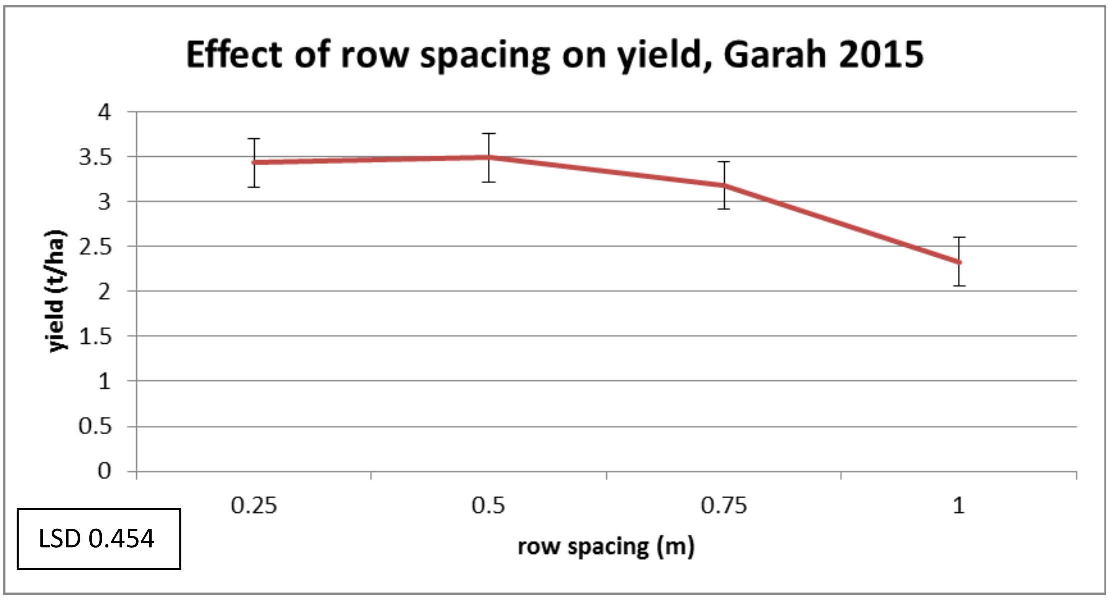


Figure 1. Effect of row spacing on yield, Garah 2015

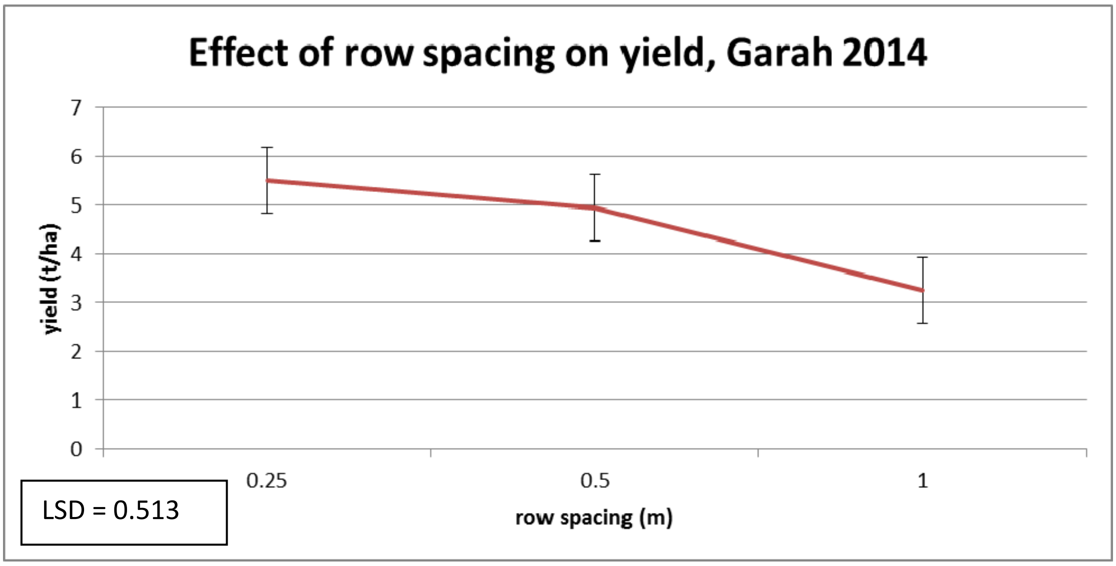


Figure 2. Effect of row spacing on yield, Garah 2014

Overall, in both years that row spacing and yield have been investigated at Garah, significant effects of the agronomic treatments were observed with both varieties responding positively to decreasing row spacing.

Effect of plant population on yield

In 2015, populations were investigated as an effect on yield however no significant differences were found between the 5, 10, 20 and 30p/m^2. It is thought that this is due to the crop 'hitting a wall' and running out of moisture at grain fill. When looking at total dry matter (t/ha) in the same crops population was different with 5p/m^2 being significantly lower than the 10, 20 and 30p/m^2 treatments. Further analysis of water use needs to be completed however early suggestions are that the crop has run out of moisture at grain fill and the plots with higher populations have had less moisture available to finish off and as a result have not been significantly higher in yield as expected at the higher planting density.

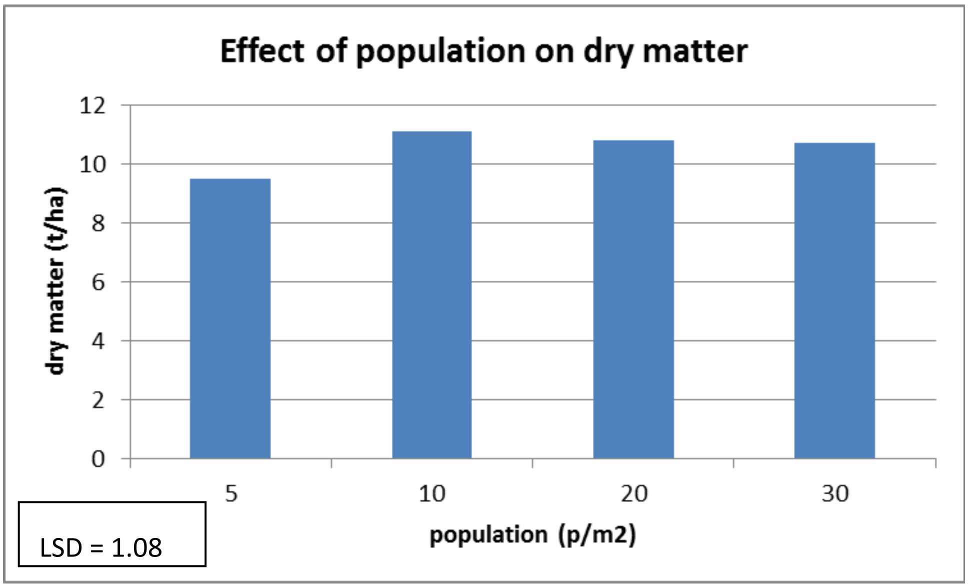


Figure 3. Effect of population on dry matter (t/ha)

Table 3. The effect of population on dry matter

population	5	10	20	30
dry matter	9.5b	11.1a	10.8a	10.7a

Effect of time of sowing on yield, drymatter and harvest index

A time of sowing trial was conducted near Dalby in winter 2014 which showed that there was a linear reduction in yield post the planting date of April 23rd; the result of this trial can be seen in figure 4.

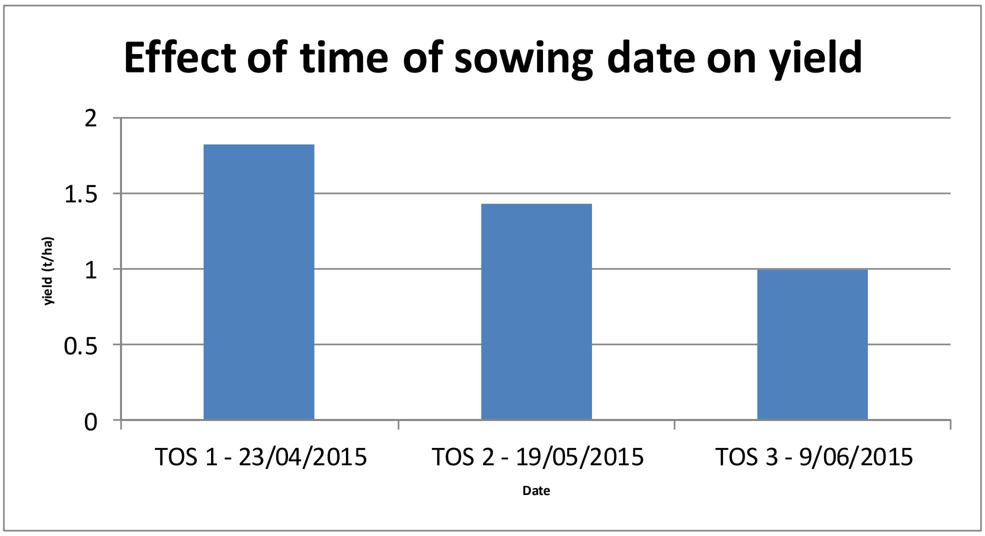


Figure 4. Effect of time of sowing date on yield, Dalby 2014

This trial was repeated in winter 2015 at the Hermitage Research Station (HRS) near Warwick, Qld and at Warra, Qld. At both locations there were three sowing dates planted at 75cm row spacing and on four targeted plant populations 5, 10, 20, $30p/m^2$. It was anticipated that the sowing dates would be 3 weeks apart however due to wet weather it was not possible. The dates used for the trial at each location can be seen in table 4.

Table 4. Sowing dates at Warra and Hermitage Research Station (HRS)

HRS 1	17/04/2015	Warra 1	9/04/2015
HRS 2	20/05/2015	Warra 2	28/04/2015
HRS 3	12/06/2015	Warra 3	21/05/2015

At HRS there was no statistical difference between the yields between the first and second time of sowing however there was a significant drop in yield of 300kg from TOS 1 and 500kg from TOS 2 out to the third sowing date.

A similar result was found at Warra, the first two sowing dates showed nil significant difference as did the difference between the second and third dates however a marked drop in yield was found between the first and third dates.

Table 5. Effect of time of sowing on yield, Warra (lsd 0.5) & HRS (lsd 0.36) 2015

	TOS 1	TOS 2	TOS 3
Warra	3.56a	3.31ab	2.84b
HRS	3.6a	3.8a	3.3b

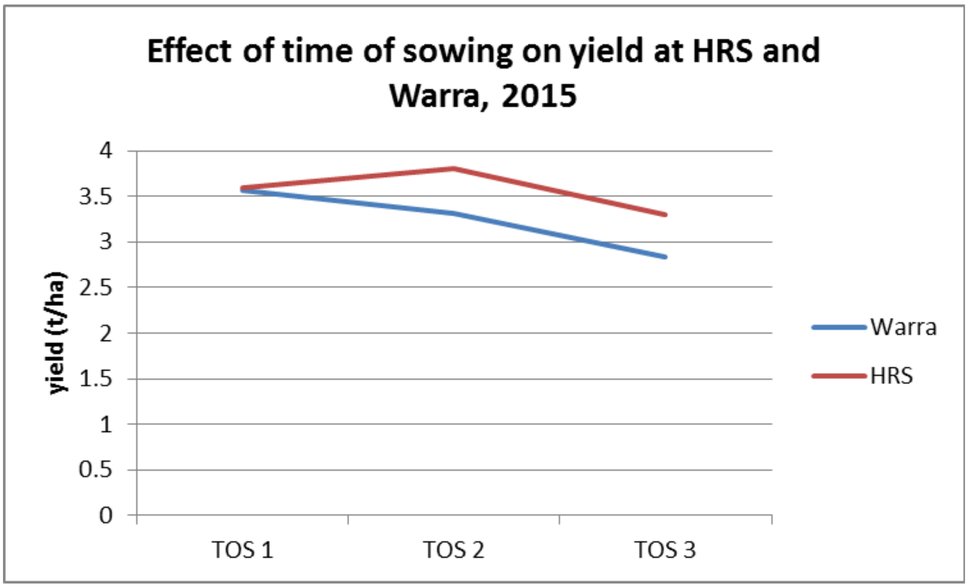


Figure 5. Effect of time of sowing on yield at HRS and Warra, 2015

From the two years of data it can be concluded that the current suggested sowing time of late April would still be appropriate and that crops planted into May and beyond could expect a linear reduction in yields. Further work could be completed with more emphasis placed on earlier sowing dates to identify if earlier than late April is appropriate.

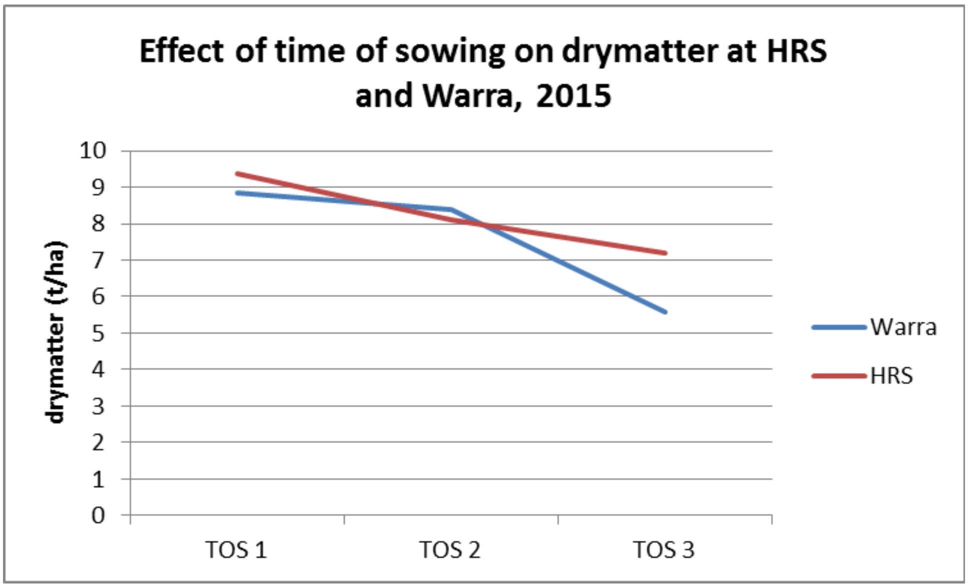


Figure 6. Effect of time of sowing on total drymatter at HRS & Warra, 2015

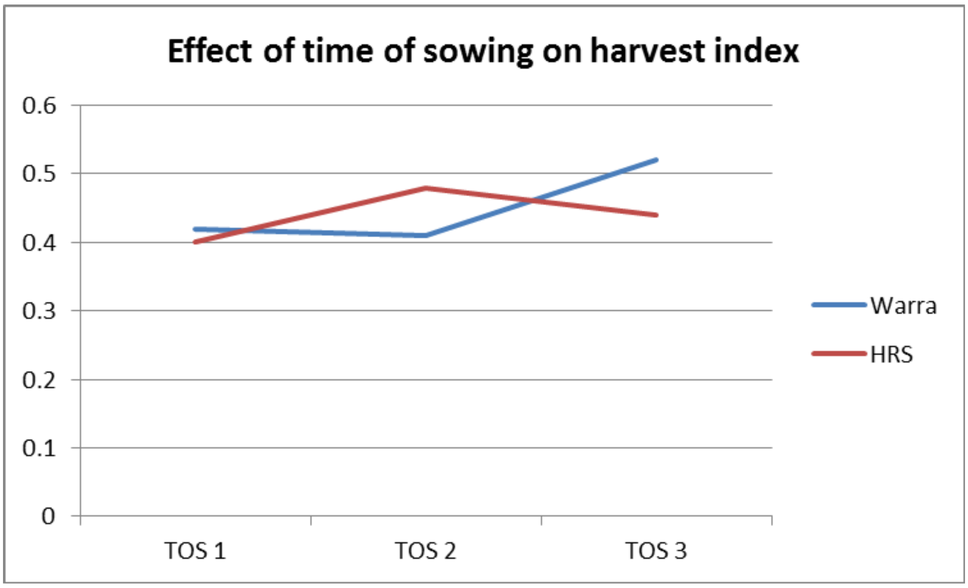


Figure 7. Effect of time of sowing on harvest index, HRS & Warra 2015
(LSD Warra – 0.08, HRS – 0.048)

Results indicate that total drymatter declines post the first TOS at both locations; the 2015 season saw crops initially grow a large amount of vegetation on available moisture however we cannot determine from this trial the reason that TOS 2 & 3 did not follow the same pattern. The harvest index has increased for TOS 2 & 3 at both locations however yield is lower. More investigation is needed into crop growth of faba beans to enable us to better understand the crop partitioning and in turn increase yield and harvest index rather than growing large biomass and not being able to convert to yield.

Effect of seed size

When using PBA Nasma⟬ as a cultivar in trials in 2014 it was found that the seed size was 25% larger and an average seed weight of 78g/100 seeds compared with the 58g/100 seeds of PBA Warda⟬ (figure 8) could pose an issue blocking airseeders. As a result of this, a trial was designed to investigate whether planting seed size has an influence on yield and also seed size of the resultant crop.

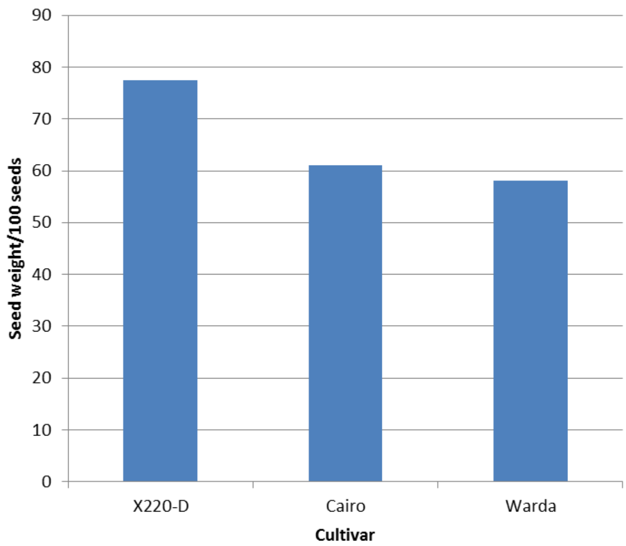


Figure 8. Faba bean seed weights by cultivar

The seed for the trial was graded into three different sizes and planted at four different populations on row spacing of 75cm. The trial was planted in May due to rainfall, which was later than anticipated and could have led to a yield reduction.

Table 6. Effect of seed size on yield

	dimensions	**Seed weight (g)**	
Size 1 (small)	25/64"	52.32	1.95a
Size 2 (medium)	28/64"	66.93	2.03ab
Size 3 (large)	33/64"	84.19	2.23b

Table 6 shows that there was a significant difference in the yield achieved between the small and large seed sizes but not between each of those and the medium seed size.

When harvested, each of the three seed size plots were then graded out into the same three sizes, the proportion of each seed size that was taken from each plot can be seen in figure 9.

Each of the sizes grew a larger proportion of medium seed than the size of its parent seed however size 1 grew more size 1 than size 3, size 2 grew more size 2 and similar amounts of size 1 and 3 and size 3 grew a larger amount of size 3 than size 1, this can be seen visually in figure 9.

It is not a recommendation to grade out larger sized seed to increase seed numbers for weight, marketing factors have not been taken into account in this trial.

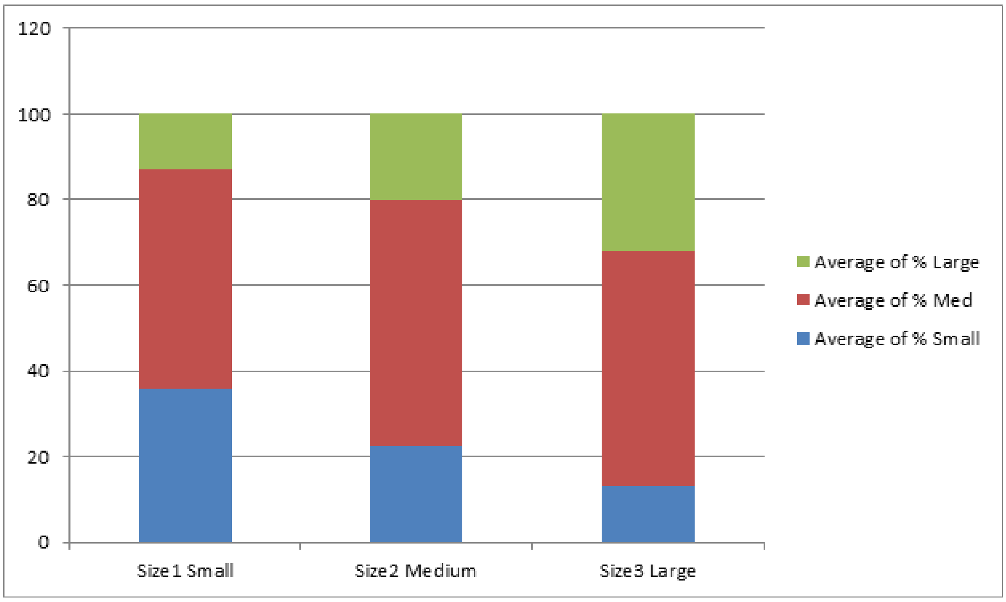


Figure 9. Effect of seed size planted on % seed size produced

Conclusion

Narrow row spacing (25/50cm) consistently yield higher than wider row spacings (75cm and above) for faba beans.

This effect has been seen across 2 years and differing seasons and environments.

Row spacing has a larger effect on yield than plant population.

Earlier planting of faba beans is best to maximise yields, however later plantings are after one year of trials producing lower biomass and as a result, higher harvest index, more investigation is required.

Acknowledgements

Many thanks for the support of Stephen Krosch, Katrina Conway, Rod O'Connor and for trial co-operators Glenn Milne, Wade Bidstrup and the Moloney Family.

Contact details

Rebecca Raymond
Department of Agriculture and Fisheries, Queensland
Mb: 0428 879 900
Email: Bec.raymond@daf.qld.gov.au

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

Northern NSW Pulse Agronomy Project –nutrition in chickpea 2015

Andrew Verrell[a] and Leigh Jenkins[b]

NSW Department of Primary Industries, Tamworth[a] and Trangie[b]

Key words

chickpea, nutrients, grain yield,

GRDC code

DAN00171 - Northern Pulse Agronomy Initiative project (winter pulses)

Take home messages

- Phosphorus was a limiting factor to grain yield in 2015
- Zinc was limiting yield at three locations
- Iron was a limiting factor on a grey-brown vertosol with a 50 year cropping history

Introduction

The 2015 season was characterised by episodic cold weather events during flowering and terminal drought during grain fill. These seasonal conditions impacted heavily, reducing the potential yield of chickpeas across most areas of the northern NSW cropping zone.

The Northern Pulse Agronomy Initiative project had a range of experiments covering a number of agronomic themes in 2014. This paper will report on the outcomes of the nutrition experiments across northern NSW.

What we did?

Nutrients were applied in a nutrient omission format at seven locations across central and northern NSW. In nutrient omission trials, one nutrient is deliberately omitted in each treatment, while all other nutrients are applied at rates considered as non-limiting. It is therefore not possible to determine optimum nutrient application rates directly from the results of these experiments.

The 12 treatments were; Zero nutrients, All nutrients, - N, - P, - K, - Ca, - B, - Cu, - Zn, - Mn, - Mg, - Fe.

Application method varied between nutrients. Both P and N were applied at sowing, at 10 kg P/ha as Trifos and 10 kg N/ha as urea, respectively. Ca, Mg, Zn, Mn, Cu and Fe were applied as chelates in a foliar spray. K was applied as Potassium citrate and B as Boron ethanolamine as foliar sprays. Besides N and P (applied at sowing), all other nutrients were sprayed on the crop at mid vegetative period. PBA HatTrick⦶ was sown at all sites at 30 plants/m^2.

What we found?

Grain yield data for the seven experimental locations is contained in Table 1. Rowena showed no significant responses to applied nutrients. The Trangie, Edgeroi and Coonamble sites showed yield responses to applied Zn of, 28%, 18% and 7%, respectively. Coonamble, Nowley, Moree and North Star had responses to applied P of, 4%, 15%, 15% and 11%, respectively.

The Coonamble site, a grey-brown vertosol which has been cropped since the early 1960's, also showed an 8% yield response to applied Fe.

Table 1. Effect of selected nutrient omission treatments on grain yield (kg/ha) in chickpea at northern NSW sites in 2015

Treatment	Trangie (kg/ha)	Rowena (kg/ha)	Edgeroi (kg/ha)	Coonamble (kg/ha)	Nowley (kg/ha)	Moree (kg/ha)	North Star (kg/ha)
Minus-Zn	559b	788a	1498b	1816b	1619a	1928a	2129a
Minus-P	626ab	986a	1613ab	1864b	1425b	1697b	2005b
Minus-Fe				1804b			
All	714a	1019a	1772a	1947a	1643a	1956a	2226a

Values with the same letter are not significantly different at P>0.05

Conclusions

- Frosts and cold periods during flowering at sites led to floral abortion and a reduction in yield;
- Extended dry periods at sites during September and October led to pod and seed abortion ;
- Older cropping country is showing responses to applied P as well as Zn and in one instance Fe

Acknowledgements

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

Contact details

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

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

Northern Winter Pulse Agronomy - Faba bean density experiments - 2015

Andrew Verrell[a] and Leigh Jenkins[b]

NSW Department of Primary Industries, Tamworth[a] and Trangie[b]

Key words

faba bean, plant density, frost

GRDC code

DAN00171 - Northern Pulse Agronomy Initiative project (Winter pulses)

Take home message

- Sow faba beans at 20 plants/m^2 in northern regions
- Sow faba beans at 30 plants/m^2 in central regions
- Doza appears more prone to frost damage than either PBA Warda or PBA Nasma

Introduction

The 2015 season was characterised by severe frost events, episodic cold weather during flowering and terminal drought during grain fill. These seasonal conditions impacted heavily on crop performance, reducing the potential yield of faba beans across most areas of the northern NSW cropping zone.

The NPAI (Winter Pulse) project conducted a range of experiments covering a number of different agronomic themes in 2015. This paper reports on the outcomes of a series of faba bean variety x density experiments across northern NSW.

What did we do?

Faba bean, variety x density, experiments were conducted at five locations across northern NSW in 2015. Three varieties were sown; Doza, PBA Warda and the new line PBA Nasma. Four target plant densities were examined; 10, 20, 30 and 40 plants/m^2. All five trials were grown under dryland cropping conditions (i.e. not irrigated).

The three lines selected represent the two preferred commercial lines (Doza and PBA Warda) and the new large seeded line PBA Nasma. The difference in seed size for these commercial lines is shown in Figure 1 where PBA Nasma, on average, has seed that is 40% larger than Doza.

What did we find?

For grain yield, there were no significant interactions between variety and plant density; only main effects (see Table 1). PBA Warda and PBA Nasma out yielded Doza at two of the five sites (Coonamble and Tamworth); while at Trangie, PBA Nasma out yielded both Doza and PBA Warda (Table 1). Plant density showed significant responses at two sites; Cryon plateaued at 20 plants/m^2, while at Trangie peak yield was obtained at 30 plants/m^2 (Table 1). The remaining sites showed no yield response to plant density.

Frosts were prevalent across the northern region in 2015 and the Tamworth site suffered a number of severe frosts. From the 28th July to the 8th of August, 6 frosts were recorded ranging from -1.3 to -3.5^{0}C. This resulted in frost damage, causing elongating stems to develop a bent stick (hockey stick) appearance and blackening of leaf margins. Treatments were scored for frost damage on a 1-9 scale on the 7th August, with 1 representing no frost damage and 9 equal to plant death. Variety ratings are shown in Figure 2 with Doza significantly worse than both PBA Warda and PBA Nasma for symptoms of frost damage.

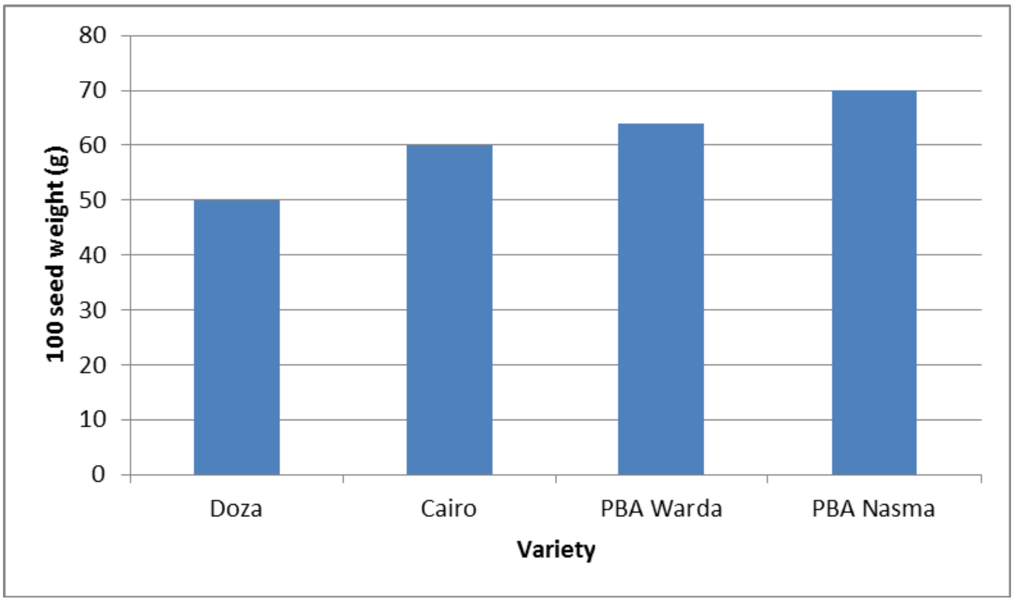


Figure 1. Average 100 seed weight (g) for selected faba bean varieties

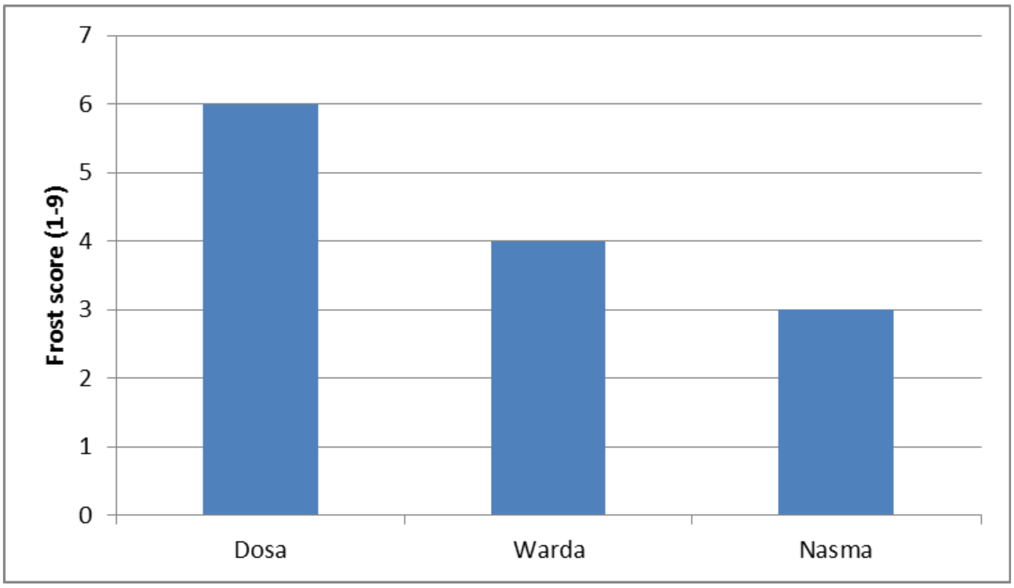


Figure 2. Frost scores for faba bean varieties (1 = no symptoms, 9 = plant death)

Table 1. Grain yield (kg/ha) for the main effects of variety and plant density at five locations in 2015

Treatment	Bullarah	Coonamble	Cryon	Trangie	Tamworth
Variety		*Grain yield (kg/ha)*			
Dozaⓓ	1602a	2900b	1547a	2036b	2954b
PBA Wardaⓓ	1687a	3280a	1700a	2246b	3296a
PBA Nasmaⓓ	1685a	3452a	1686a	2658a	3359a
Density		*Grain yield (kg/ha)*			
10	1498a	3376a	1373b	1975c	3177a
20	1670a	3411a	1772a	2275b	3329a
30	1768a	3246a	1673a	2515a	3210a
40	1666a	3270a	1745a	2489a	3096a

Values with the same letter are not significantly different

Conclusion

Limited data from the first year of trial results in 2015 suggests that for northern and western sites 20 plants/m^2 is a preferred target plant density, while in southern areas 30 plants/m^2 is a better option to achieve optimum yield of faba beans grown under dryland cropping conditions.

Large seed does not necessarily confer higher yield; with PBA Nasmaⓓ out yielding PBA Wardaⓓ at only one location, Trangie.

Dozaⓓ appears more prone to frost damage than either PBA Wardaⓓ or PBA Nasmaⓓ. Frost tolerance is a key attribute for the faba bean breeding program in northern NSW, with new releases (particularly PBA Nasmaⓓ) targeted at having better tolerance than Dozaⓓ.

Acknowledgements

The research undertaken as part of project DAN00171 is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC. The authors would like to thank them for their continued support. Thanks to Michael Nowland, Matt Grinter, Jayne Jenkins, Scott Richards and Gerard Lonegran (all NSW DPI) for their assistance in the trial program.

Contact details

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

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

PBA Nasma faba bean – effect of seed size at sowing on grain yield

Andrew Verrell[a] and Leigh Jenkins[b]

NSW Department of Primary Industries, Tamworth[a] and Trangie[b]

Key words

faba bean, seed size, frost, grain yield

GRDC code

DAN00171 - Northern Pulse Agronomy Initiative project (Winter pulses)

Take home messages

- At present, there is no evidence to suggest that seed size at sowing has an impact on grain yield in cultivar PBA Nasma
- Seed size at sowing is positively related to seed size at harvest
- Further experimentation is needed

Introduction

In cereals, large initial seed size frequently confers distinct advantages in terms of seedling vigour, hardiness, improved stand establishment, and higher productivity (Grieve and Francois, 1992). Spilde (1988) found, for barley and wheat that grain produced from small-sized seed averaged 4 and 5% less yield than that from medium sized seed and 6 and 8% less yield than that from large-sized seed, respectively.

However, studies comparing faba bean genotypes of different seed sizes indicated a negative relationship between seed mass and grain yield (Laing *et al*., 1984; White and González, 1990; White *et al*., 1992; Sexton *et al*., 1994). Lima *et al* (2005) found faba bean plants originating from small seed presented a higher relative growth rate and net assimilation rate than plants from large seed. Large seed did not affect grain yield, but reduced the number of seeds per pod, increased the 100-seed mass, and reduced the harvest index.

The new faba bean cultivar, PBA Nasma, produces very large seed averaging 70g/100 seeds compared to cultivar Doza, at 50g/100 seeds . An experiment was conducted to examine the effect of seed size at sowing, at a fixed population, on grain yield and seed size distribution at harvest.

What did we do?

Seed supply for this newly released cultivar was in limited supply which restricted experimentation to two sites (TAI and TARC) in 2015.

The seed was passed thru a set of nested circular mesh sieves and partitioned into four seed size categories; < 7mm, 7-8mm, 8-9mm, >9mm. The corresponding 100 seed weights for the seed size categories, < 7mm, 7-8mm, 8-9mm, >9mm; were 34.6, 48.1, 69.5 and 90.0g, respectively.

Randomised complete block experiments consisting of the four seed size treatments and four replicates were sown at target plant densities of 20 and 10 plants/m^2 at TAI and TARC, respectively.

What did we find?

The seed size distribution of the 25kg seed lot used to obtain the seed categories for sowing these experiments is contained in Figure 1. The predominant seed size was the 8-9mm category which accounted for 72% of the total seed supply.

All plots attained their target plant densities (data not shown). At TAI, plants grown from the largest size seed produced 19% and 8% more biomass than the small seed size category at 25th June and 3rd August, respectively. Seed size categories were scored for frost damage on the 7th of August but there was no significant difference.

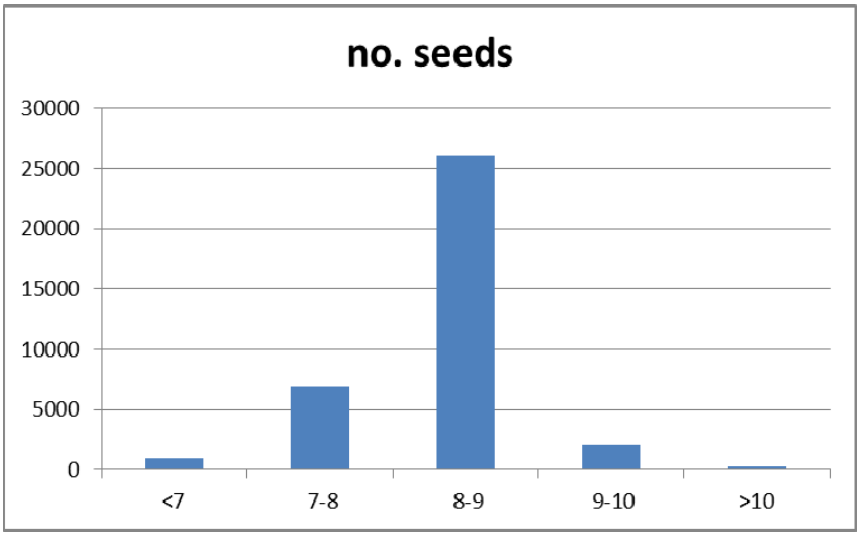


Figure 1. Seed size distribution and number of seeds per category for the seed lot used for sowing experiments.

Table 1 contains data on the effect of seed size category at sowing on plant height, height to top pod, grain yield and hundred seed weight for the TAI experiment and grain yield and 100 seed weight for the TARC experiment.

At TAI, the plants grown from seed smaller than 7mm in size were significantly shorter than all other seed categories while there was no difference in height to top pod across the seed categories (see Table 1). There was also no significant difference in grain yield between any of the seed size categories. Hundred seed weight did vary significantly and the large seed category, on average, produced heavier grain than the small seed category.

At TARC, grain yield was significantly higher for the two large seed size categories compared to the very small seed category (by 13%). Hundred seed weight had a similar response to seed size category as found at TAI, 100 seed weight increasing with seed size at sowing (see Table 1).

Table 1. Effect of seed size category at sowing on plant height, height to top pod, grain yield and hundred seed weight for TAI and grain yield and hundred seed weight for TARC

		TAI			TARC	
Seed size category	**Plant height (mm)**	**Height to top pod (mm)**	**Yield (kg/ha)**	**100 seed weight (g)**	**Yield (kg/ha)**	**100 seed weight (g)**
<7mm	1240b	1000a	3287a	55.80c	1696 c	48.1d
7-8mm	1358a	1124a	3144a	65.0ab	1726bc	50.9c
8-9mm	1329a	1030a	3267a	59.4bc	1921ab	55.2b
>9mm	1376a	1078a	3557a	68.80a	2013 a	60.0a

Values with the same letter are not significantly different at P>0.05

Conclusion

Plants grown from large seeds were taller and had significantly more biomass than the plants grown from small seed. However this did not translate into a significant difference in grain yield at TAI but did in the TARC experiment. There may be an interaction with plant density and seed size given these different results (TAI 20 and TARC 10 plants/m^2). These results are similar to that of Agung and McDonald (1998) in South Australia where yields for cultivar Fiord averaged about 400 g/m 2 but were not consistently related to seed size, although the highest yielding accession at their sites were large-seeded.

The size of seed produced at harvest was positively related to seed size with the largest seed category producing the biggest size seed compared to the small seed category (see Table 1) at both experimental sites.

Acknowledgements

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

References

S. Agung and G. K. McDonald (1998). Effects of seed size and maturity on the growth and yield of faba bean (Vicia faba L.). Australian Journal of Agricultural Research 49(1) 79 - 88

C. M. Grieve, L. E. Francois (1992). The importance of initial seed size in wheat plant response to salinity. Plant and Soil, Vol 147, Issue 2, pp 197-205

Laing DR, Jones PG, Davis JHC (1984) Common bean (Phaseolus vulgaris L.). In: Goldsworthy PR, Fisher NM (eds), The Physiology of Tropical Field Crops, pp.305-351. John Wiley, New York, USA.

Elvis Rodrigues Lima; Aline Silva Santiago; Adelson Paulo AraújoII, Marcelo Grandi Teixeira (2005). Effects of the size of sown seed on growth and yield of common bean cultivars of different seed sizes, Braz. J. Plant Physiol. vol.17 no.3

Sexton PJ, White JW, Boote KJ (1994) Yield-determining processes in relation to cultivar seed size of common bean. Crop Sci. 34:84-91.

L. A. Spilde (1988). Influence of Seed Size and Test Weight on Several Agronomic Traits of Barley and Hard Red Spring Wheat. Journal of Production Agriculture, Vol. 2, No. 2, p. 169-172

White JW, González A (1990) Characterization of the negative association between seed yield and seed size among genotypes of common bean. Field Crops Res. 23:159-175

White JW, Singh SP, Pino C, Rios BMJ, Buddenhagen I (1992) Effects of seed size and photoperiod response on crop growth and yield of common bean. Field Crops Res. 28:295-307.

Contact details

Dr Andrew Verrell

NSW Department Primary Industries

Mb: 0429 422 150

Email: andrew.verrell@dpi.nsw.gov.au

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

Integrated management of crown rot in a chickpea – wheat sequence

Andrew Verrell, NSW Department of Primary Industries, Tamworth

Key words

row placement, row spacing, wheat, stubble, chickpea

GRDC code

DAN00171 - Winter pulse agronomy project

Take home message

- Sow chickpea crops between standing wheat rows
- Sow the following wheat crop *directly* over the row of the previous year chickpea crop
- Keep wheat stubble intact and do not spread it across the surface

Introduction

Crown rot, caused by the stubble-borne fungus *Fusarium pseudograminearum* (*Fp*), remains a major limitation to winter cereal production across the northern grains region of Australia. Crop sequencing with non-host crops, has proven to be one of the best means of reducing the impact of crown rot (CR) infection (by 3.4-41.3%) and increasing wheat yield (by 0.24-0.89 t/ha) compared to a cereal-wheat sequence (Kirkegaard *et al.* 2004, Verrell *et al*. 2005). While inter-row sowing has been shown to reduce the impact of CR and increase yield, by up to 9%, in a wheat-wheat sequence (Verrell *et al* 2009). Verrell *et al.* (2014) showed that using mustard-wheat and chickpea-wheat crop sequencing resulted in a 40-44% increase in wheat yield over a continuous wheat system under zero-tillage and adding inter-row sowing increased wheat yield by a further 11-16% depending on the row placement sequences.

Chickpea are the most prevalent break crop grown in sequence with wheat in the northern NSW region. Chickpea crops are reliant on the use of post-sow pre-emergent residual herbicides (Group C and H) for broadleaf weed control and a common commercial practice is to level the seeding furrow after sowing, usually with Kelly chains, to avoid the risk of herbicide residue concentrating in the furrows and causing damage. The consequence of leveling the seed furrow to avoid possible herbicide damage is that any standing wheat residue, under a zero-tillage system, is shattered and spread across the entire soil surface. If this wheat residue is infected with *Fp* then CR inoculum is no longer confined to the standing wheat rows.

There was a need to examine whether integrating row placement, stubble management, chickpea row spacing and ground engaging tool would affect the incidence of *Fp* and grain yield in wheat in a chickpea– wheat sequence grown under a zero-tillage system.

What did we do?

A three year crop sequence experiment (wheat-chickpea-wheat) was established at Tamworth in 2012 to examine the effect of ground engaging tool, chickpea row spacing, row placement and wheat residue management on the incidence of *Fp* and grain yield of a wheat crop.

In 2012, durum wheat (EGA Bellaroi⦸) was sown into a cultivated paddock using a Trimble® RTK auto-steer system fitted to a New Holland TL80A tractor with narrow row crop tyres. The crop was sown with a disc seeder on 40 cm row spacing and bulk harvested with the residue cut at a uniform height of 24 cm.

In 2013, chickpea (cv. PBA HatTrick⦸) was sown at 80 kg/ha and treatments consisted of; main-plot was row placement; (between or on 2012 wheat rows), sub-plot was stubble management; (standing or slashed and spread), sub-sub plot was row spacing; (narrow 40 cm or wide 80 cm) and sub-sub-sub plots were ground engaging tool; (Barton® single disc opener or Janke® coulter-tyne-press wheel parallelogram). The stubble management treatments was applied after the plots were sown.

In 2014, wheat (cv. EGA Gregory⦸) was sown over the chickpea plots and treatments consisted of; sub-sub plots as row placement; (between or on 2012 wheat rows) and sub-sub-sub plots were ground engaging tool; (Barton single disc opener or Janke coulter-tyne-press wheel parallelogram).

What did we find?

Chickpea grain yield increased when sown with a disc opener (by 6%), on narrow rows (by 22%) and sown between the 2012 wheat rows (by 7%) but stubble management did not have a main effect on chickpea yield. However, stubble management had a significant interaction with row spacing where sowing chickpeas on narrow rows (40 cm) into standing residue out yielded narrow rows where the residue had been slashed (by 6%) (see Figure 1). There was no significant yield effects with chickpeas sown on wide rows (80 cm) whether the wheat residue was left standing or slashed.

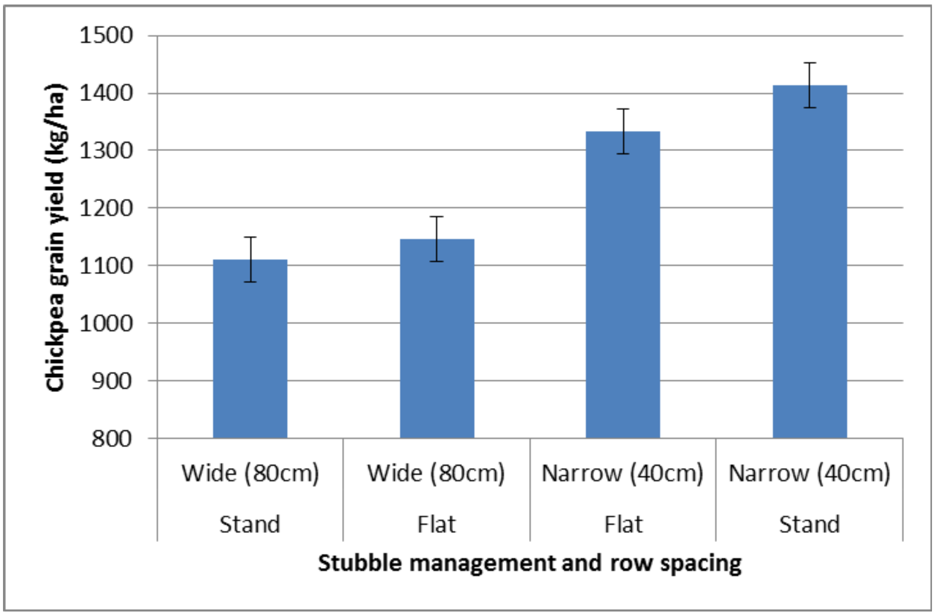


Figure 1. Effect of row spacing and wheat stubble management on chickpea grain yield (kg/ha)

In the 2014 wheat crop, sowing with a coulter-tyne-press wheel out yielded the disc opener (by 6.3%). Row placement of the wheat (relative to the 2012 wheat crop) had a significant interaction with the stubble treatment in the 2013 chickpea crop. Where wheat was sown into the space between the old wheat rows (2012) and the stubble was left standing in the 2013 chickpea crop resulted in the highest grain yield (3718 kg/ha) (see Fig. 2). This was significantly higher than the other row x stubble combinations; on-row x flat, on-row x standing and between-row x flat which yielded, 3585, 3515 and 3487 kg/ha, respectively, which were not significantly different from one another.

The incidence of *Fp* at harvest, as main effects, was lower where chickpeas had been sown between wheat rows (6.6%) compared to on the row (10.0%) and lower when stubble was left standing (6.4%) compared to spreading (9.9%). The type of ground engaging tool, row spacing in the previous chickpea crop or row placement of the 2014 wheat crop had no significant main effect on the incidence of *Fp* at harvest. For the narrow row (40 cm) chickpea system; sowing on the old wheat row led to a significant increase in the incidence of *Fp* at harvest in the following wheat crop (11.8%) compared to sowing between the old wheat rows (5.8%).

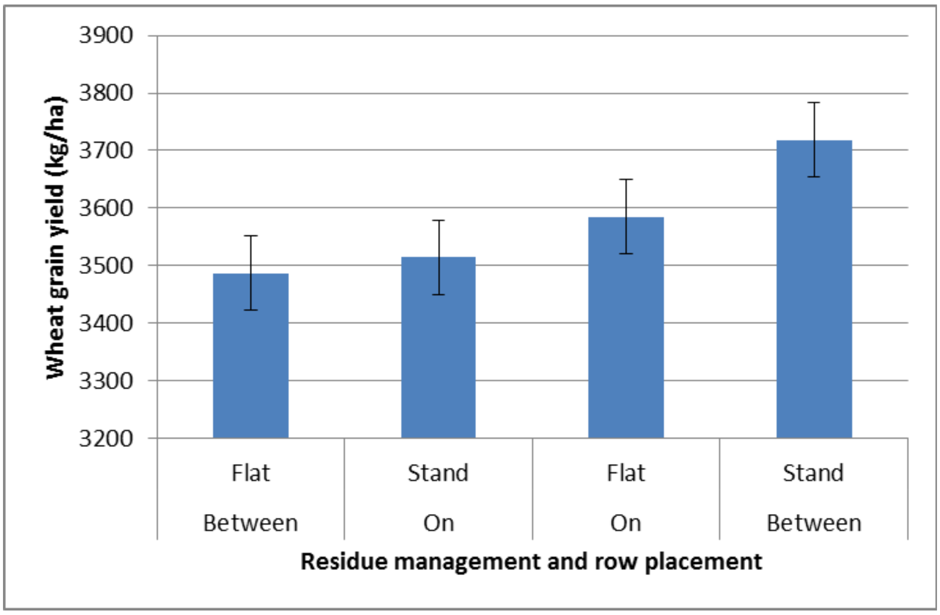


Figure 2. Effect of row placement (relative to the 2012 wheat crop) and stubble management in the 2013 chickpea crop on grain yield (kg/ha) in the 2014 wheat crop

Under the wide row (80 cm) chickpea system; row placement had no effect on the incidence of *Fp* (mean 7.5%). Sowing the 2013 chickpea crop between standing wheat rows and the following wheat crop directly over the previous chickpea row and between the old wheat rows resulted in the lowest incidence of *Fp* (4.6%) (see Fig. 3).

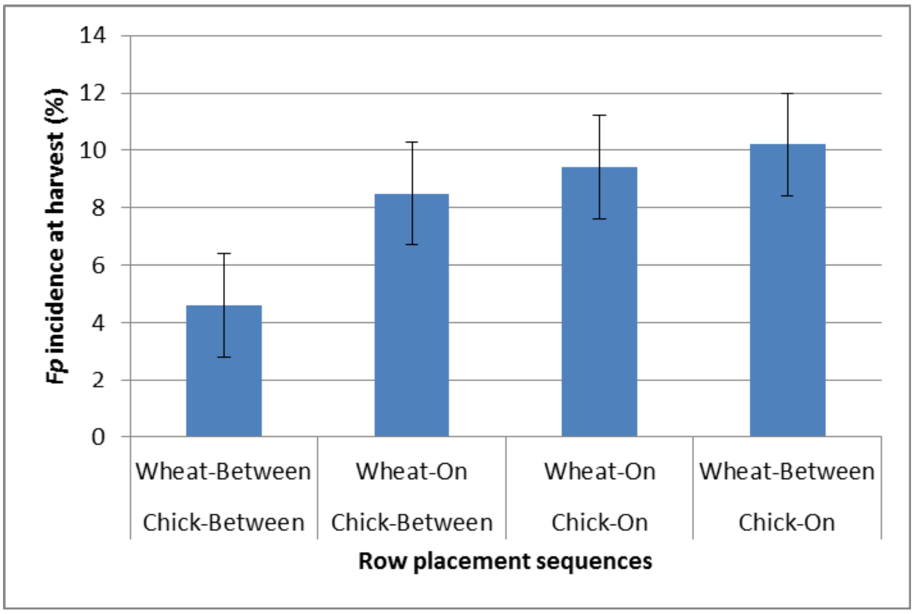


Figure 3. The interaction of chickpea row placement (2013) and wheat row placement (2014) on the incidence of *Fp* in wheat

Other row placement combinations; chickpea between wheat rows x wheat on-rows, chickpea on wheat rows x wheat on-rows, and chickpea on-rows x wheat between wheat rows resulted in *Fp* levels of 8.5, 9.4 and 10.2%, respectively.

Conclusion

At Tamworth in 2013, sowing chickpea on narrow rows (40 cm) realised a 22% yield advantage over wide rows (80 cm). Also sowing chickpeas between standing wheat rows resulted in a higher yield (by 6%) compared to sowing the crop then slashing the wheat stubble and spreading it across the surface. Growing chickpeas between standing wheat stubble has been shown to provide a yield advantage in previous studies largely by reducing the incidence of aphid transmitted viruses (Verrell and Moore 2015).

The highest wheat yield (3718 kg/ha) came from sowing the wheat into the inter row space of the old wheat crop (2 years old) and keeping the stubble standing. Using a tyne also resulted in a yield advantage over a disc opener. When stubble was left standing the incidence of *Fp* was lower (6.4%) compared to spreading stubble across the surface (9.9%). Sowing the 2013 chickpea crop between standing wheat rows and the following wheat crop directly over the previous chickpea row and between the old wheat rows resulted in the lowest incidence of *Fp* (4.6%). Any stubble management practice which spreads residues into the inter row space is likely to undo row placement benefits associated with reducing the incidence of crown rot infection, as *Fp* inoculum is no longer confined to the standing wheat rows. The perceived crop safety benefits of leveling the seeding furrow after applying post-sow pre-emergent residual herbicides (Group C and H) in chickpeas needs to be balanced against potential impacts on chickpea yield and increased incidence of crown rot infection in the following winter cereal crop.

Acknowledgements

The research undertaken as part of project DAN00171 is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. Thanks to Michael Nowland and Paul Nash (NSW DPI) for their assistance in the trial program. *Fp* levels were kindly determined through laboratory plating by the NSW DPI Cereal Pathology Group based at Tamworth.

References

Verrell, A.G., Simpfendorfer S., Nash P. and Moore K. (2009) Can inter-row sowing be used in continuous wheat systems to control crown rot and increase yield? 13th Annual Symposium on Precision Agriculture in Australasia (2009), UNE, Armidale.

Verrell, A.G., Simpfendorfer S., Nash P. and Moore K. (2005) Crop rotation and its effect on crown rot, common root rot, soil water extraction and water use efficiency in wheat. Proceedings 2005 GRDC Grains Research Update, Goondiwindi.

Verrell A (2014) Managing crown rot through crop sequencing and row placement. GRDC. Available at: http://grdc.com.au/Research-and-Development/GRDC-Update%20Papers/2014/07/Managing-crown-rot-through-crop-sequencing-and-row-placement

Verrell A and Moore KJ (2015). Managing viral diseases in chickpeas through agronomic practices Australian Agronomy Conference, Hobart.

Contact details

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

Reviewed by Dr Steven Simpfendorfer

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

Chickpeas – what we learnt in 2015 and recommendations for 2016

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

Key words

chickpea, Ascochyta, Phytophthora, management

GRDC code

DAN00176 Northern NSW Integrated Disease Management

Take home message

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

The 2015 northern NSW/southern QLD chickpea season

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

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

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

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

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

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

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

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

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

Chickpea diseases in 2015

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

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

The mild wet winter also favoured Sclerotinia (24 cases) especially in paddocks with a canola history, with both basal and aerial infections detected. Where canola was involved, the species was always

S. sclerotiorum. One crop in the wetter areas east of Narrabri had aerial infection from ascospores of *S. minor* instead of the typical infection of roots and stem base by mycelia from sclerotia. This was the first record in this region for infection from windborne ascospores from sclerotia (due to carpogenic germination of sclerotia) leading to infection of chickpea by of *S. minor*. If such windborne infection is common, greater *S. minor* infection may result.

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

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

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

Disease management recommendations for 2016

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

Table 3. Chickpea seed treatments

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

Ascochyta Blight

The following strategy should reduce losses from Ascochyta in 2016:

- In areas where AB was detected in 2015, spray all varieties, including PBA HatTrick⊕ and PBA Boundary⊕ with a registered Ascochyta fungicide prior to the first rain event after crop emergence, three weeks after emergence, or at the 3 branch stage of crop development, whichever occurs first.
- In areas where AB was NOT detected in 2015, spray all varieties with AB resistance lower than PBA HatTrick⊕ with a registered Ascochyta fungicide prior to the first rain event after crop emergence, three weeks after emergence, or at the 3 branch stage of crop development, whichever occurs first.
- 2-3 weeks after each rain event, monitor all crops irrespective of variety and spray if Ascochyta is detected in the crop or is found in the district on any variety.

- Ground application of fungicides is preferred. Select a nozzle such as a DG TwinJet or Turbo TwinJet that will produce no smaller than medium droplets (ASAE) and deliver the equivalent of 80–100 litres water/hectare at the desired speed.
- Where aerial application is the only option (e.g. wet weather delays) ensure the aircraft is set up properly and that contractors have had their spray patterns tested.

Botrytis grey mould, BGM

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

Phytophthora root rot

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

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

http://www.grdc.com.au/Resources/Factsheets/2013/05/Chickpea-disease-management

www.pulseaus.com.au

- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/ascochyta-blight
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/northern-guide#Diseasemanagement
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/idm-strategies
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/botrytis-grey-mould
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/phytophthora-root-rot
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/sclerotinia
- http://www.pulseaus.com.au/growing-pulses/publications/manage-viruses

and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

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

Contact details

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

® Registered trademark

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

Chickpea on chickpea – is it worth it?

Kevin Moore, Kristy Hobson and Sean Bithell, NSW DPI

Key words

chickpea, Ascochyta, Phytophthora, Sclerotinia, management

GRDC codes

DAN00176, DAN00151

Take home message

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

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

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

Background

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

What are the risks of back to back chickpea?

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

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

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

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

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

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

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

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

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

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

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

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

There are three:

1. Increased risk of changes in the pathogen ie it becomes more virulent and aggressive
2. Reduced commercial life of varieties ie back to back chickpea increases the risk of the pathogen establishing in the crop early which increases the potential for more disease cycles throughout the growing season which means resistance genes are subjected to more challenges by the pathogen. Resistance genes are limited; the loss of any gene will severely hinder the development of new chickpea varieties.
3. Increased risk of pathogens developing resistance to fungicides ie reduced life of fungicide. For diseases that can be managed with in-crop fungicides eg Ascochyta, the earlier the disease establishes, the more likely is the need for repeated applications of fungicides. If you wanted to find resistance to chlorothalonil in the Ascochyta pathogen, a good place to look would be in early sown back to back Kyabraⓓ. The problem here is that any isolate that is resistant to chlorothalonil is unlikely to be confined to the paddock (or farm) in which that resistance developed. Thus an Ascochyta isolate with resistance to chlorothalonil on a single farm in say Moree could become established in the Darling Downs and elsewhere in northern and north central NSW within a few seasons. This would be the end of chlorothalonil as a disease management tool for chickpeas.

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

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

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

http://www.grdc.com.au/Resources/Factsheets/2013/05/Chickpea-disease-management

www.pulseaus.com.au

- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/ascochyta-blight
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/northern-guide#Diseasemanagement
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/idm-strategies
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/botrytis-grey-mould
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/phytophthora-root-rot
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/sclerotinia
- http://www.pulseaus.com.au/growing-pulses/publications/manage-viruses

and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

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

Contact details

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

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

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

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

Chickpea Ascochyta – latest research on variability and implications for management

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

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

Key words

chickpea, Ascochyta, pathogenicity, latent period

GRDC code

DAN00176, UM00052, DAN00151, DAV00126, DAN00151, DAV00098

Take home message

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

Ascochyta blight in 2015 chickpea crops

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

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

Latest research on variability in the Ascochyta pathogen

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

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

Latent period

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

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

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

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

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

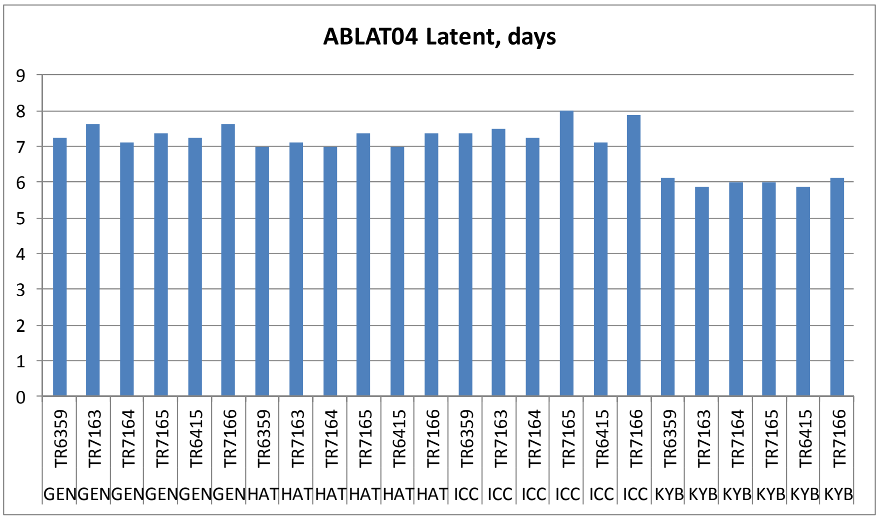


Figure1. Latent period results for experiment ABLAT04 grouped by genotype (ICC3996 (ICC), Genesis 090 (GEN), PBA HatTrick⦶ (HAT), Kyabra⦶ (KYB)) for inoculation with six isolates listed by isolate no, source and variety: TR6359 2014 North Star NSW, Flipper⦶; TR7165 2014 Horsham VIC; Genesis425, TR7163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

Histopathology experiments

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

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

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

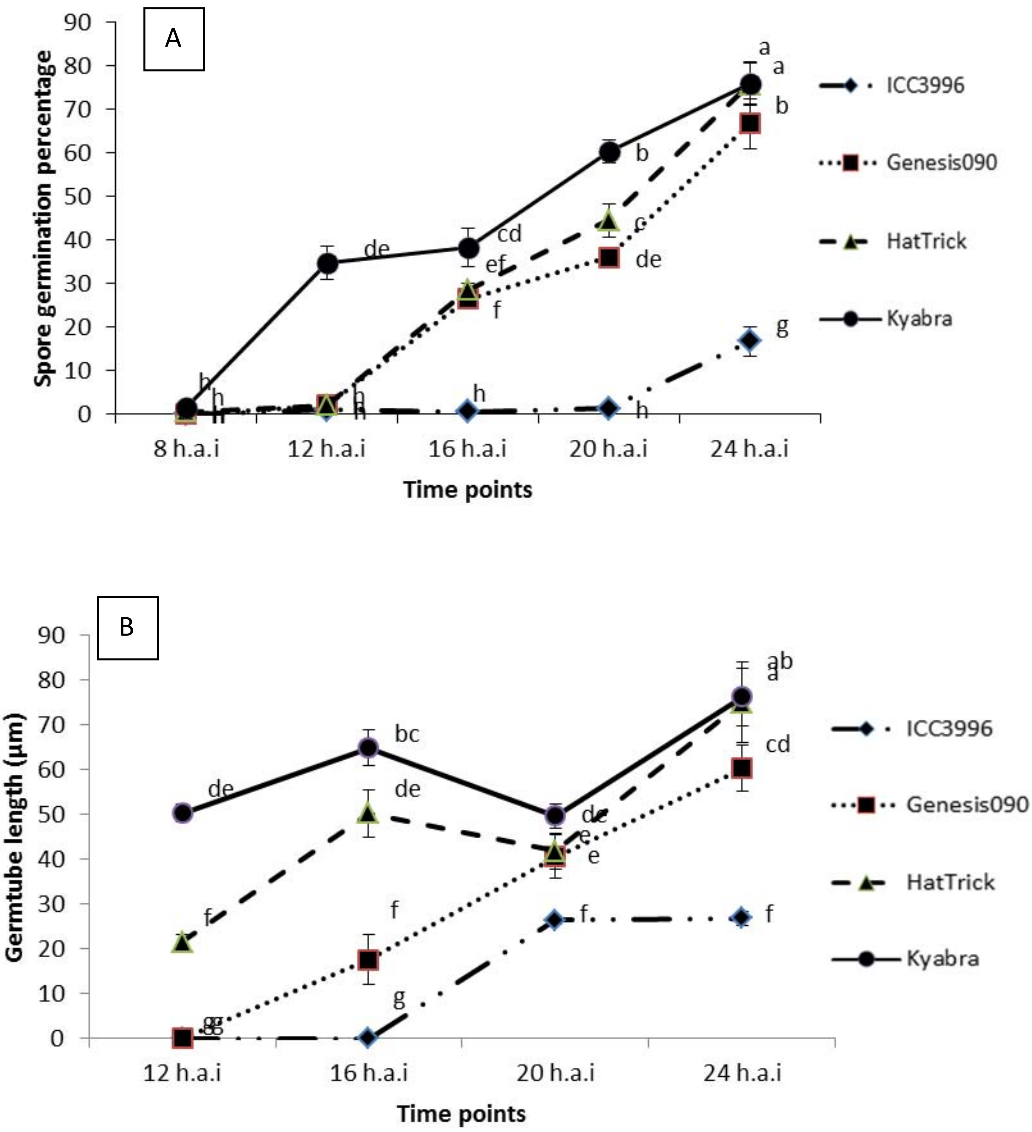


Figure 2. Significant differences were observed among the physiological traits of a highly pathogenic isolate FT13092-1 from Kingsford, SA when inoculated onto chickpea genotypes that are resistant (ICC3996 and Genesis090), moderately resistant (PBA HatTrick) or susceptible (Kyabra). Where A = the percentage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

How is this information used by the PBA Chickpea program?

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

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

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

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

*Advanced breeding lines, putative AB rating

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

Further information

http://www.grdc.com.au/Resources/Factsheets/2013/05/Chickpea-disease-management

www.pulseaus.com.au

- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/ascochyta-blight
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/northern-guide#Diseasemanagement
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/idm-strategies
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/botrytis-grey-mould
- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/phytophthora-root-rot

- http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/sclerotinia
- http://www.pulseaus.com.au/growing-pulses/publications/manage-viruses

and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

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

Contact details

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

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

® Registered trademark

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

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

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

Key words

Ascochyta, variety, management

GRDC code

DAN00176, DAN00151

Take home message

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

2015 Tamworth Ascochyta management trial, VMP15

VMP15 sought to evaluate Ascochyta blight (AB) management using ten varieties/advanced breeding lines with a range of Ascochyta resistance ratings: seven desis Kyabra (S, susceptible), PBA HatTrick (MR, moderately resistant), PBA Boundary (MR), CICA0912 (putatively R, resistant), CICA1007 (putatively MR), CICA1302 (for CQ, putatively MR) and CICA1303 (for CQ, putatively MR) plus the kabulis Genesis Kalkee™ (rated MS), PBA Monarch (MS, moderately susceptible) and Genesis 425™ (rated R).

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

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

Key findings of VMP15 (see Table 2) were:

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

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

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

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

The findings below contrasted between the two VMP experiments

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

Table 1. VMP15 2015 dates, number of rain days (>1 mm rain), mm of rain and dates and number of 1 L/ha chlorothalonil applications, trial sown 18-19 May. *trial was AB inoculated on 16 June

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

The following factors in VMP15 may have contributed to the nil PBA HatTrick⒟ treatments having poorer yields than in prior VMP trials:

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

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

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

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

Variety and treatment		No. Sprays	Cost $/ha	Yield kg/ha	GM $/ha
CICA0912	1.0L	7	105	1853	984
Genesis425	1.0L	7	105	1875	1470
CICA1007	1.0L	7	105	1846	982
PBA Boundaryⓓ	1.0L	7	105	1755	876
PBA Monarchⓓ	1.0L	7	105	1274	869
PBA HatTrickⓓ	1.0L	7	105	1722	852
CICA1302	1.0L	7	105	1864	954
CICA1303	1.0L	7	105	1949	1018
Kyabraⓓ	1.0L	7	105	1862	954
Kalkee	1.0L	7	105	1659	1254
CICA0912	Nil	0	0	1568	844
Genesis425	Nil	0	0	1144	844
CICA1007	Nil	0	0	1083	491
PBA Boundaryⓓ	Nil	0	0	1233	600
PBA Monarchⓓ	Nil	0	0	887	587
PBA HatTrickⓓ	Nil	0	0	417	4
CICA1302	Nil	0	0	0	-300
CICA1303	Nil	0	0	0	-300
Kyabraⓓ	Nil	0	0	0	-300
Kalkee	Nil	0	0	1589	1289

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

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

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

Acknowledgements

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

Contact details

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

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

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

™ Registered Trademark

Phytophthora in chickpea varieties HER15 trial –resistance and yield loss

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

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

Key words

Phytophthora root rot, variety, risk management

GRDC code

DAN00176, DAN00151, DAQ00186, DAS00137

Take home message

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

Varietal resistance to phytophthora root rot

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Acknowledgements

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

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

Contact details

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

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

A new DNA tool to determine risk of chickpea Phytophthora root rot

Sean Bithell[1], Kevin Moore[1], Kristy Hobson[1], Steve Harden[1], Willy Martin[2] and Alan McKay[3]

[1]NSWDPI, Tamworth, NSW; [2]DAFQ Warwick, [3]SARDI, Adelaide, SA

Key words

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

GRDC code

DAS00137, DAN0172, DAN0176

Take home message

- Increasing level of inoculum (oospores/plant) of *Phytophthora medicaginis* (Pm) was strongly correlated with decreasing yield of the moderately resistant variety Yorker
- An inoculum level of 660 oospores/plant (PreDicta B® > 5000 Pm copies/g soil) at sowing significantly reduced yields compared with lower inoculum levels under both dryland and irrigated conditions
- Testing soil samples from growers' 2015 paddocks confirmed the results of testing 2014 samples that the PreDicta B® soil Pm test can identify Pm in growers paddocks in NSW and QLD
- These findings provide further evidence that the PreDicta B® Pm test will be a useful tool for growers to determine their risk of Phytophthora root rot

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 (*Pm*), the cause of chickpea Phytophthora root rot (PRR) is endemic and widespread in southern QLD and northern and north central NSW. Under conducive conditions, PRR can cause 100% loss. The pathogen survives from season to season on chickpea volunteers, lucerne, native medics, sulla and as resistant structures (oospores) in roots and soil.

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 the second season of studies to assess the capability of this test to:

1. detect Pm inoculum in soil from commercial paddocks
2. predict the risk of PRR disease and potential yield losses in chickpea

***Pm* inoculum level, PRR disease and yield**

It would be useful if the Pm DNA test could predict the amount of PRR disease and potential losses. For example, would paddocks with nil, low and high Pm inoculum levels have nil, low and high PRR disease and yield losses? Our 2014 Pm inoculum concentration field trial (Tamworth) using the PRR susceptible variety Sonali (rating S) showed that yield losses were greatest at the highest soil Pm concentrations but that even at low soil concentrations (100 oospores/plant) substantial yield loss occurred. Pm is able to multiply quickly under high soil water conditions. The 2014 trial showed that following a saturating rain event, the amount of disease and extent of yield loss with medium levels of inoculum (500 and 1000 oospores/plant) caught up with those of higher levels of inoculum (2000 and 4000 oospores/plant)

The aim of the 2015 field trial (DAF Qld Hermitage Research Station, Warwick, QLD) was to relate the Predicta B® Pm test to PRR level and yield loss for low inoculum levels (<1000 oospores/plant) using the most PRR resistant variety Yorker⏀ (rating MR), under dryland and irrigated conditions. Irrigation was included to specifically test if low inoculum treatments would have similar effects on disease and yield loss to those of high inoculum treatments under disease conducive conditions. On 10 June 2015, a range of Pm inoculum levels was established by applying, at sowing, different rates of oospores in-furrow. On 10-11 Jun, thirty soil samples (150 mm depth cores) per plot (5 reps) were pooled and tested for soil Pm concentration by PreDicta B®. The trial was also sampled for end-season DNA Pm concentrations on 15 December (data not available at time of writing).

Irrigation was applied on 10-11 Sep and on 16-17 Oct following 2 weeks with low rainfall (< 3mm). Winter rainfall was similar to long term average values for July (22mm) and August (25mm) but September and October both had below average rainfall totals. November was wet with 97mm of rain.

Soil Pm DNA values at sowing differed significantly among oospore treatments but not between irrigation treatment (Table 1). Three of ten Nil (0) oospore plots had positive but low Pm DNA results, indicating background Phytophthora in some plots.

On 13 Oct (end of flowering), the irrigated 130 and 660 oospores/plant treatments had significantly more PRR than the dryland 130 and 660 oospores/plant treatments (Table 1). By 12 Nov (dryland treatments senescing), the irrigated 40, 130 and 660 oospores/plant treatments had significantly more PRR than the dryland 40, 130 and 660 oospores/plant treatments.

The interaction of irrigation and oospore treatments on grain yield was complex as indicated by (Table 1, Figure 1):

(i) at low inoculum levels (zero and 40 oospores/plant), irrigation increased yield compared with dryland

(ii) for medium inoculum (130 oospores/plant), irrigation had no significant effect on yield

(iii) for the highest inoculum level (660 oospores/plant) irrigation reduced yield compared with the dryland treatment.

These interactions suggest that at low PRR levels, the primary effect of irrigation is on yield, but at high PRR levels the primary effect is on disease. However, the shape of these relationships are likely to vary from season to season due to differences in seasonal rainfall (Figure 1).

Furthermore multiple processes will affect outcomes. For example, although yields did not differ between the irrigated and dryland 130 oospores/plant treatments (~3000 P.med DNA seq no/g soil) there was more disease in the irrigated treatment. In this 2015 trial, the uninfected irrigated plants in a plot will have had grain yield benefits from irrigation and so probably compensated for the yield loss of infected plants. However, for seasons with above average early-season rainfall there may be greater early-season disease development and hence greater impacts on yield at this same 3000 P.med DNA seq no/g soil inoculum level.

Under PRR conducive conditions, can low initial levels of inoculum catch up to high initial levels with regard to disease severity and yield loss? This is not clear from the current experiment and further research is required.

Can the Pm DNA soil test predict risk of Phytophthora? Based on the results of this trial with Yorker⏀ (MR) and the 2014 Tamworth one with Sonali (S), the answer is YES. For Yorker⏀ significant yield loss can be expected with starting (pre-sow sampling) inoculum levels above ca 3000 Pm DNA sequences/g soil (ca 130 oospores/plant).

However, these values may need to be interpreted with some caution as seasonal conditions will modify outcomes, for instance in a dry season less disease may develop from the same amount of inoculum.

Table 1. Irrigation-oospore treatment, soil Pm DNA concentration, PRR assessment and yield of Yorker⊕ in 2015 Pm inoculum trial at Warwick, QLD (Soil Pm concentration: $P < 0.001$; LSD 1092.6; 13 Oct PRR rating: $P = 0.038$; LSD = 0.58; 12 Nov row cm of PRR stunted plants: $P = 0.035$; LSD 46.4; Grain yield: $P<0.001$; LSD = 480.7)

Treatment, dryland (D), irrigated (I), no. oospores per plant	Soil Pm DNA concentration at sowing no. Pm sequences/g soil	13 Oct PRR rating (1= no disease, 9 = all plants dead)	12 Nov. cm of row of PRR stunted plants	Grain yield, kg/ha
D-0	342	1.1	16	3198
D-40	1986	1.7	18	2961
D-130	3051	2.0	88	3038
D-660	5357	3.1	203	2402
I-0	169	1.2	6	3914
I-40	1765	1.8	78	3631
I-130	2996	2.8	185	2966
I-660	5925	4.2	395	1764

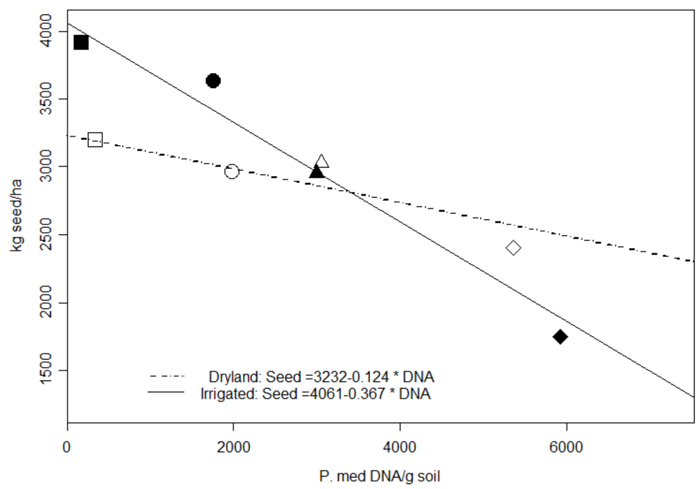


Figure 1. Multiple regression for plot soil Pm concentrations at sowing vs. grain yield for dryland (black symbols) and irrigated (white symbols) treatments (model $R^2 = 0.745$), treatment means presented.

Pm DNA detection in soil samples from commercial paddocks

We evaluated the ability of the Pm DNA test to detect Pm in soil samples from growers' paddocks.

Over the winter-spring period of 2014, soil samples were collected from fields in central (16) and south-western Queensland (10), and Victoria (7). Most paddocks included chickpeas in the rotation but not all had chickpeas in 2014. There were eight perimeter sample sites per paddock, one near each corner and one near the midpoint of each side. At each of the eight sample sites, a W collection pattern was walked towards the centre of the paddocks and 10 soil cores (150 mm depth PreDicta B® soil corer) collected every 20 – 25 paces along the sample path (total distance 200 – 250 m per sample site), giving a total of 80 soil cores.

Samples (9) were also collected from southern NSW, in this case most paddocks included either lucerne or lupins in the rotation. For these sites a diagonal collection pattern across low lying and weedy areas of paddocks was used and 80 150mm PreDicta B® cores collected per site.

Soil samples were stored in sealed plastic bags at 5°C. Samples were homogenised by cutting up cores and mixing, following which a 400g sub sample was sent to SARDI for DNA analysis. The remainder of each sample was then restored at 5°C until the baiting experiment was setup.

Samples from 43 paddocks were prepared for DNA analysis and a Pm baiting experiment. Subsamples of soil were dried at 105°C for 24h to determine soil moisture content, then non-dried soil was mixed with sand (dry weight basis, 55g soil + 154g sand), placed in a plastic cup (70mm width, 75mm height). There were five reps; soil from a Pm inoculated field trial (MET14) served as a control. Three Sonali seeds were sown in each cup, the cups placed in a glasshouse (RCB design). The cups were watered to 21% soil moisture content three times a week. After 18 days the cups were flooded for 48h then drained. Seedlings were assessed for disease (chlorosis, stem cankers, death) three times a week. Stem canker 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. The isolation of Pm was attempted from all treatments that produced chlorosis followed by the appearance of Pm like stem cankers, in addition, the isolation of Pm was also attempted from any treatments where there were disease symptoms or seedlings with poor growth. After eight weeks the experiment was terminated.

Ten of the 43 paddock soil treatments produced PRR like cankers on plants, Pm like cultures were isolated from eight samples from growers paddocks; Pm like cultures were also isolated from the MET14 control soil, giving a total of nine Pm isolates. One of the samples (NIE1) produced cankers that were not caused by Pm.

Of the 43 paddock soil treatments (including the MET14 control soil), 9 had positive Pm DNA results. Comparing the DNA results to the isolation results showed that most (8/9, 89%) samples which had positive DNA results also yielded Pm cultures and that most (33/34, 97%) samples which had negative DNA results also did not yield Pm cultures (Table 2).

Notably, one sample (LOU2) which yielded a Pm culture was negative for Pm DNA.

One sample (A) was positive for Pm DNA but did not yield Pm cultures, seedlings in all 5 cups remained healthy. This sample that did not produce any PRR symptoms had a lower Pm DNA value (1,234 Pm copies/g soil) than other samples (range 2,443-813,436 Pm copies/g soil). Possible explanations for this result is: (i) more time may be required for symptoms to develop, or (ii) that the pathogen had died but some DNA had been detected.

Table 2. Comparison of *Phytophthora medicaginis* (Pm) DNA detection in 43 paddock soil samples and isolation success of Pm from Sonali chickpeas grown in these samples

		43 samples analysed for Pm DNA	
		9/43 + Pm DNA	34/43 nil Pm DNA
43 soil samples baited with chickpeas for Pm	9/43 + Pm isolates	8/9 (positives)	1/34 (false negatives)
	34/43 nil Pm isolates	1/9 (false positives)	33/34 (negatives)

These second season of results for the capability of the soil Pm DNA test are again generally promising, with most samples with positive and negative Pm DNA results corresponding to expected Pm isolation results. However, results for some samples indicate that further work is required to a) identify what factors may contribute to false negative results and b) determine if false positives are due to the presence of dead or inactive Pm DNA.

***Pm* DNA sampling in paddocks and disease risk determination**

The DNA result for a soil sample from a paddock can only provide an indication of inoculum concentration and disease risk for the areas of the paddock which were sampled. Therefore, the spread and locations of sampling across a paddock will affect how representative DNA results are for a paddock. Because of the risk of rapid PRR disease build up following wet conditions it may be appropriate to treat a negative Predicta B® test result as indicating a low risk rather than a nil risk, as the pathogen could still be in areas of the paddock that were not sampled and so still cause PRR and reduce yield.

To maximise the probability of determining the PRR risk of a paddock, target those areas of the paddock where Pm is more likely to occur. The pathogen thrives in high soil moisture contents and so often occurs in low lying regions of paddocks where pooling following rain may occur. The pathogen also carries over from season to season on infected chickpea volunteers, lucerne and, native medics. Including low lying areas and weedy areas of paddocks during PreDicta B® soil sampling may provide the best strategy to identifying a paddocks disease risk of PRR in chickpea.

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

Acknowledgements

This research is made possible by the significant contributions of growers through both trial cooperation, paddocks access and the support of the GRDC, the authors would like to thank them for their continued support. Kurt Lindbeck (NSW DPI), Frank Henry ( ) and Peter Keys (DAFQ) kindly located sample sites. Thanks to Gail Chiplin and Kris King for technical support

Contact details

Sean Bithell & Kevin Moore
NSW Department Primary Industries
Ph: 0429 201 863 & 0488 251 866
Fx: 02 6763 1100
Emails: sean.bithell@dpi.nsw.gov.au & kevin.moore@dpi.nsw.gov.au

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

® Registered trademark