# GRDC Grains Research Update Moree

**Tuesday 28th July 2015, RSL**

Registration: 8:30am for a 9am start, finish 3:05 pm

## Agenda

| Time | Topic | Speaker (s) |
|---|---|---|
| 9:00 AM | Welcome | GRDC |
| 9:10 AM | Crown-rot - latest research: stubble management; sowing between the rows; issues where nematodes are also present; are new seed dressings an option? | Steve Simpfendorfer, NSW DPI |
| 9:40 AM | Nematodes - strategies for managing blowout paddocks back to profit. | Discussion session with Richard Daniel, NGA & Steve Simpfendorfer, NSW DPI and local advisers |
| 10:10 AM | The what, where and why of soil testing for crop nutrition in the Moree area. What's changed? | Mike Bell, QAAFI |
| 10:40 AM | Morning tea | |
| 11:10 AM | Optimising sorghum profit in NNSW - an update of recent research with guidelines on agronomy for 2015. | Loretta Serafin, NSW DPI |
| 11:45 AM | Grain sorghum variety reactions to heat stress and environment – what are they and why the differences? | Scott Chapman, CSIRO |
| 12:20 PM | Farming systems performance: A major new farming systems project on the constraints to performance and efficiency. What's planned, where and how to engage. | Lindsay Bell, CSIRO |
| 12:35 PM | Lunch | |
| 1:35 PM | Ascochyta update - what's happening in the paddock - bringing home the 2015 crop safely. | Kevin Moore, NSW DPI |
| 2:05 PM | Quality defects in chickpeas - causes, management options, and research in progress. | Jenny Wood, NSW DPI |
| 2:25 PM | NGA weeds research update: Comparison of new herbicide options for problem weeds in chickpeas; Residual chemistry in crops and fallow. | Richard Daniel, NGA |
| 2:50 PM | Discussion of strategies for driving down seedbanks of barnyard grass. | Discussion session |
| 3:05 PM | Close | |

## Contents



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# Crown rot: an update on latest research

*Steven Simpfendorfer, NSW DPI Tamworth*

**Key words**

Stored soil water, inoculum, PreDicta B, yield loss, variety tolerance, root lesion nematodes

**GRDC code**

DAN00175: National crown rot epidemiology and management program

**Take home message**

- Impact of crown rot on yield and quality is a balance between inoculum levels and soil water
- The balance is heavily tipped towards soil water yet most management strategies tend to focus solely on combating inoculum, sometimes to the detriment of soil water
- Cultivation (even shallow) distributes infected residue more evenly across paddocks and into the infection zones below ground for crown rot. This IS NOT good!
- Some of the newer wheat varieties appear promising in that they provide improved tolerance to crown rot
- PreDicta B is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing within paddocks. However, this requires a dedicated sampling strategy and IS NOT a simple add on to a soil nutrition test

**Introduction**

Crown rot, caused predominantly by the fungus *Fusarium pseudograminearum* is a significant disease of winter cereals in the northern region. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, while major yield loss from the production of whiteheads is related to moisture stress post-flowering. It is critical that growers understand that there are three distinct and separate phases of crown rot, namely ***survival, infection*** and ***expression.*** Management strategies can differentially effect each phase.

***Survival:*** the crown rot fungus survives as mycelium (cottony growth) inside winter cereal (wheat, barley, durum, triticale and oats) and grass weed residues, which it has infected. The crown rot fungus will survive as **inoculum** inside the stubble for as long as it remains intact, which varies greatly with soil and weather conditions as decomposition is a *very slow* process.

***Infection:*** given some level of soil moisture the crown rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, sub-crown internode or crown tissue which are all below the soil surface. The fungus can also infect plants above ground *right at* the soil surface through the outer leaf sheathes. However, with all points of infection, direct contact with the previously infected residues is required and infections can occur throughout the whole season given moisture. Hence, wet seasons favour increased infection events by the crown rot fungus when combined with the production of greater stubble loads significantly builds-up inoculum levels.

***Expression:*** Yield loss is related to moisture/temperature stress around flowering and through grain-fill. This stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the stems, and producing whiteheads that contain either no grain or lightweight shrivelled grain. The **expression** of whiteheads in plants infected with crown rot (i.e. still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture/temperature stress during grain-fill. Focus attention to crops around trees within a paddock or along tree lines. Even in good years whiteheads associated with crown rot infection are likely to be seen around trees. This is due to the extra competition for water.

**How to manage crown rot**

*Crop rotation*

The most effective way to reduce crown rot inoculum is to include non-susceptible crops in the rotation sequence. The crown rot fungus can survive for two to three years in stubble and soil. Growing a non-host crop for at least two seasons is recommended to reduce inoculum levels. This allows time for decomposition of winter cereal residues that host the crown rot fungus. Stubble decomposition varies with the type of break crop grown – their canopy density and rate of the canopy closure as well as row spacing, the amount of soil water they use and seasonal rainfall. **Trials in the northern region have indicated that faba beans and canola are better break crops for crown rot than chickpeas.**

*Cultivation*

Growers may cultivate their stubble for a range of reasons e.g. to reduce trash load prior to sowing. However, the effect of cultivation on crown rot is complex as it potentially impacts on all three phases of the disease cycle.

*Survival:* stubble decomposition is a microbial process driven by temperature and moisture. Cultivating stubble in theory increases the rate of decomposition as it reduces particle size of stubble, buries these particles in the soil where microbial activity is greater and the soil environment maintains more optimal moisture and temperature conditions compared to the soil surface or above ground. However, cultivation also dries out the soil in the cultivation layer, which immediately limits the potential for decomposition of the incorporated stubble. Decomposition of cereal stubbles is a *very slow* process that requires adequate moisture for an extended period of time to occur completely. A summer fallow (even if extremely wet and stubble has been cultivated) is **not** long enough!

*Infection:* as covered earlier, the majority of infection sites with crown rot are below ground and physical contact between an infected piece of residue and these plant parts is required to initiate infection. Cultivation of winter cereal stubble harbouring the crown rot fungus effectively breaks the inoculum into smaller pieces and spreads them more evenly through the cultivation layer across the paddock. Consequently, the crown rot fungus has been given a much greater chance of coming into contact with the major infection sites below ground as the next winter cereal crop germinates and develops. In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in a no-till cropping system. Cultivation or harrowing negates the option of inter-row sowing as a crown rot management strategy.

*Expression:* extensive research has shown that cultivation dries out the soil to the depth of cultivation and reduces the water infiltration rate due to the loss of structure (macropores etc). The lack of cereal stubble cover can also increase soil evaporation. With poorer infiltration and higher evaporation, fallow efficiency is reduced for cultivated systems compared to a no-till stubble retention system. Greater moisture availability has the potential to provide buffering against crown rot expression late in the season. Like crown rot management and all farming practices, cultivation is a balancing act between perceived benefits and costs.

*Stubble burning*

Burning removes the above ground portion of crown rot inoculum but the fungus will still survive in infected crown tissue below ground so it is **not** a 'quick fix' for high inoculum situations. Removal of stubble through burning will increase evaporation from the soil surface and impact on fallow efficiency. A 'cooler' autumn burn is therefore preferable to an earlier 'hotter' burn as it minimises the negative impacts on soil moisture storage whilst still reducing inoculum levels.

*Reduce water loss*

Inoculum level is important in limiting the potential for yield loss from crown rot but the overriding factor dictating the extent of yield loss is moisture/temperature stress during grain-fill. Any management strategy that limits storage of soil water or creates constraints that reduce the ability of roots to access this water will increase the probability and/or severity of moisture stress during grain-fill and exacerbate the impact of crown rot.

*Grass weed management*

Grass weeds should be controlled in fallow periods and in-crop, especially in break crops, as they host the crown rot fungus and can also significantly reduce soil moisture storage. In pasture situations grasses need to be cleaned out well in advance of a following cereal crop as they serve as a host for the crown rot fungus.

*Row placement*

In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in a no-till cropping system. Further research conducted by NSW DPI has also demonstrated the benefits of row placement in combination with crop rotation and the relative placement of break crop rows and winter cereal rows within the sequence to limit disease and maximise yield (Verrell 2014 GRDC Updates). Sowing break crops between standing wheat rows which are kept intact then sowing the following wheat crop directly over the row of the previous years break crop ensures 4 years between wheat rows being sown in the same row space. This substantially reduces the incidence of crown rot in wheat crops, improves establishment of break crops (esp. canola) and chickpeas will benefit from reduced virus incidence in standing wheat stubble.

*Soil type*

Soil type does not differentially affect the survival or infection phases of crown rot. However, the inherent water holding capacity of each soil type interacts with expression by potentially buffering against moisture stress late in the season. Hence, yield loss can be worse on red soils compared to black soils due to their generally lower water holding capacities. Any other sub-soil constraint e.g. sodicity, salinity or shallower soil depth effectively reduces the level of plant available water which can increase the expression of crown rot.

*Cereal crop and variety choice*

All winter cereal crops host the crown rot fungus. Yield loss varies between crops and the approximate order of increasing loss is oats, barley, triticale, bread wheat and durum.
Barley is very susceptible to crown rot infection and will build up inoculum but tends to suffer reduced yield loss through its earlier maturity relative to wheat. Late planted barley can still suffer significant yield loss especially when early stress occurs within the growing season.
Bread wheat varieties appear to differ significantly in their level of yield loss to crown rot with newer

varieties in the northern region (Sunguard⦸, Suntop⦸, LRPB Spitfire⦸, LRPB Lancer⦸ and Mitch⦸) appearing to suffer less yield impacts compared to the widely grown EGA Gregory. NSW DPI trials from a total of 23 sites in 2013/14 conducted across the northern region indicate that this can represent a yield benefit of around 0.50 t/ha in the presence of high levels of crown rot infection.

However, **variety choice is NOT a solution to crown rot** with even the best variety still suffering up to 40% yield loss from crown rot under high infection levels and a dry/hot seasonal finish. All current durum varieties are very susceptible to crown rot and should be avoided in medium and high risk situations.

*Sowing time*

Earlier sowing within the recommended window of a given variety for a region can bring the grain-fill period forward and reduce the probability of moisture and temperature stress during grain-fill. Earlier sowing can increase root length/depth and provide greater access to deeper soil water later in the season, which buffers against crown rot expression. This has been shown in previous NSW DPI research across seasons to reduce yield loss from crown rot. Earlier sowing however can place a crop at risk of frost damage during its most susceptible time. Sowing time in the northern region is a balancing act between the risk of frost and heat stress. However, when it comes to crown rot, increased disease expression with delayed sowing can have just as big an impact on yield as frost. The big difference from NSW DPI trial work is the additional detrimental impact of later sowing on grain size in the presence of crown rot infection.

### Interaction with root lesion nematodes

Root lesion nematodes (RLNs) are also a wide spread constraint to wheat production across the region. Two important species of RLN exist throughout the northern region, namely *Pratylenchus thornei* (*Pt*) and *P. neglectus* (*Pn*). Previous surveys of the northern NSW have found that *Pt* is more widespread and generally at higher populations than *Pn.* RLNs feed inside the root systems of susceptible winter cereals creating lesions and reducing lateral branching. This reduced the efficacy of the root system to extract soil water and nutrients which subsequently can exacerbate the expression of crown rot. Varieties with reduced tolerance of *Pt* can suffer significantly greater yield loss from crown rot if both of these pathogens are present within a paddock.

### How do I know my level of risk for crown rot and RLN?

PreDicta B is a DNA based soil test which detects levels of a range of cereal pathogens that is commercially available to growers through the South Australian Research and Development Institute (SARDI). Because the crown rot fungus is stubble-borne, normal soil samples are unreliable and disease detection is highly sensitive to the sampling technique used. Follow the specific protocols for how to collect samples for crown rot testing (further paper in these proceedings).

If you are not willing to follow the recommended PreDicta B sampling strategy then DO NOT assesses disease risk levels prior to sowing.

### Further reading

GRDC Grains Research Update paper (July 2014) on Managing crown-rot through crop sequencing and row placement, Andrew Verrell, NSW DPI

### Acknowledgments

This paper includes some older information conducted in collaboration with Northern Growers Alliance as acknowledged in the text and crop sequences in combination with row placement research was conducted by Dr Andew Verrell (NSW DPI). This information has been presented in greater detail at previous GRDC Updates with full reports available at www.grdc.com.au. Technical assistance provided by Robyn Shapland, Finn Fensbo, Karen Cassin, Kay Warren, Rod Bambach, Peter Formann, Stephen Morphett and Jim Perfrement are gratefully acknowledged.

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# Update on a dedicated sampling strategy to improve the accuracy of PreDictaB® soil testing to identify crown rot risk

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**Key words**

DNA soil testing, disease risk, crown rot, root lesion nematodes

**GRDC codes**

DAS00137 – National improved molecular diagnostics for disease management
DAN00175 – National crown rot epidemiology and management program

**Take home messages**

- PreDicta B® is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing within paddocks. However, this requires a dedicated sampling strategy and IS NOT a simple add on to a soil nutrition test.
- Soil cores should be targeted at the previous winter cereal row if evident and RETAIN any stubble fragments.
- Short pieces of stubble (two from each PreDicta B® soil sampling location) from previous winter cereal crops and/or grass weed residues can be added to the soil sample to enhance detection of the *Fusarium* spp. that cause crown rot.
- 'Spiking' with stubble will reduce the likelihood of 'failure to warn' situations for crown rot but unfortunately will also increase the probability of false warnings.

**Introduction**

PreDicta B® is a DNA based soil test which detects levels of a range of cereal pathogens that is commercially available to growers through the South Australian Research and Development Institute (SARDI). The main pathogens of interest in the northern grains region detected by PreDicta B® are *Fusarium* spp. (crown rot), *Bipolaris sorokiniana* (common root rot), *Pythium* (damping off) and both *Pratylenchus thornei* and *P. neglectus* (root lesion nematodes, RLNs). Over recent years PreDicta B® has been shown to be a reliable method for assessing RLN populations but is perceived by industry to be less reliable in assessing levels of crown rot risk in the northern region.

Between 2010 and 2012, we conducted an annual winter cereal pathogen survey of 248 paddocks across 12 districts in central and northern NSW. The three-year survey measured the DNA levels of the *Fusarium* pathogen at sowing against the infection levels that had developed by harvest. This research found that in 75% of paddocks, PreDicta B® at sowing predicted the actual level of infection that developed in the crop as measured after harvest within one risk category. In 3% of paddocks PreDicta B® overestimated the risk of infection compared to actual development levels (false warning) but of more concern was that PreDicta B® underestimated the risk of crown rot in 22% of paddocks (failure to warn).

The underestimation of crown rot risk is potentially due to the crown rot fungus being stubble-borne while PreDicta B® is a soil based test. Further investigation found that soil nutrition sampling strategies were often being used to collect both the soil nutrition and PreDicta B® samples. This is significant because soil nutrition samples are normally collected between the rows with stubble removed whereas PreDicta B® samples need to be collected along the row of the previous cereal crop and incorporate any stubble residues.

Improving the accuracy and calibrating PreDicta B® in the northern region for crown rot is important for advisers and growers to better plan their crop and varietal selection prior to winter crop sowing and avoid costly yield losses from this disease. This is particularly relevant leading into the 2015 cropping season with a high durum grain price last season likely to see many growers considering durum this year. Durum is highly susceptible to crown rot so the cost of getting it wrong and sowing into a high disease risk paddock is significant.

The following paper reports on collaborative research conducted by NSW DPI and SARDI across central/northern NSW in 2013 to improve the accuracy of the PreDicta B® test in assessing crown rot risk by fine tuning soil sampling techniques and recommendations.

**Detection issue?**

Currently there are three separate tests within PreDicta B® that detect common *Fusarium* species causing crown rot across Australia - two tests which detect variations in *F. pseudograminearum* populations and a third test which detects both *F. culmorum* and *F. graminearum* but cannot differentiate between these two species. The failure to warn of the risk of crown rot in 22% of paddocks could be related to the inability of the current PreDicta B® tests to actually detect other species/variants of *Fusarium* causing crown rot across the region. A national survey was conducted in 2013 and 2014 with over 800 *Fusarium* isolates collected from wheat and barley plants with basal browning characteristic of crown rot infection from across Australia. Molecular analysis determined that all *Fusarium* species known to cause crown rot are being detected by the current PreDicta B® assays. Hence, there is no detection issue with the current PreDicta B® tests that could contribute to the underestimation of crown rot risk.

**Does the addition of stubble ('spiking') improve PreDicta B® assessment of crown rot risk?**

In 2013 each of the six ranges in 13 cereal NVT sites and 8 NSW DPI district pathology (DP) trials were cored using PreDicta B® (Table 1). Two separate soil samples were collected from each range at each of the 21 field sites spread from central NSW up into southern Qld. All cores were targeted at the previous winter cereal rows if evident. Previous winter cereal crop stubble was also collected across each separate range at coring if present and used to spike set soil samples. Twenty-five lowest nodes (1 cm segments around node) were cut from the corresponding stubble sample and added to one of the samples collected from each range. All samples were then sent to SARDI for PreDicta B® analysis.

**Table 1.** Location of field trial sites in 2013

| Site no. | Location | Site No. | Location |
|---|---|---|---|
| 1 | NVT Bellata | 12 | NVT Westmar |
| 2 | NVT Bullarah | 13 | NVT Wongarbon |
| 3 | NVT Coolah | 14 | DP Narrabri |
| 4 | NVT Coonamble | 15 | DP Terry Hie Hie |
| 5 | NVT Gilgandra | 16 | DP Bithramere |
| 6 | NVT Macalister | 17 | DP Spring Ridge |
| 7 | NVT Merriwa | 18 | DP Tamworth |
| 8 | NVT North Star | 19 | DP Garah |
| 9 | NVT Spring Ridge | 20 | DP Rowena |
| 10 | NVT Trangie | 21 | DP Macalister |
| 11 | NVT Tulloona | | |

After harvest stubble was collected from all plots of three varieties (EGA Gregory⁽ᴰ⁾, Suntop⁽ᴰ⁾ and Caparoi⁽ᴰ⁾ or Spitfire⁽ᴰ⁾) at each site. Twenty-five crowns from each plot were trimmed, surface sterilised and plated onto laboratory media to determine the incidence of crown rot infection that developed during the 2013 based on the recover of *Fusarium.*

PreDicta B® risk for crown rot is a sum of all three *Fusarium* tests which are then converted to a log scale to normalise the data. Current PreDicta B® crown rot risk categories for durum wheat are used in the northern region and corresponding harvest infection levels based on plating have also been developed for the region (Table 2).

**Table 2.** Current PreDicta B® crown rot risk levels and corresponding harvest infection level

| **PreDicta B® (log *Fusarium* DNA/g soil)** | **Risk or harvest disease level** | **Incidence of infection (% *Fusarium* recovery)** |
|---|---|---|
| <0.6 | Below detection limit (BDL) | <2 |
| 0.6 – 1.4 | Low | 3-12 |
| 1.4 – 2.0 | Medium | 13-24 |
| >2.0 | High | ≥25 |

Addition of stubble fragments to soil samples was only possible at few sites with previous cereal stubble being present at 7 (red larger diamonds, Figures 1 & 2) of the 21 sites (2, 4, 5, 8, 12, 16 and 18). The addition of stubble increased the crown rot risk level at six of the sites, from low to high at 2 sites (sites 4, NVT Coonamble and 12, NVT Westmar), low to medium at 2 sites (sites 5, NVT Gilgandra and 8, NVT North Star) and medium to high at 2 sites (sites 2, NVT Bullarah and 18, DP Tamworth) (Figure 1 and 2). For the last site (site 16, DP Bithramere) the log *Fusarium* DNA/g increased from 2.5 to 4.3 with the addition of stubble but this did not increase the predicted crown rot risk level as both values represented a high risk of crown rot development.

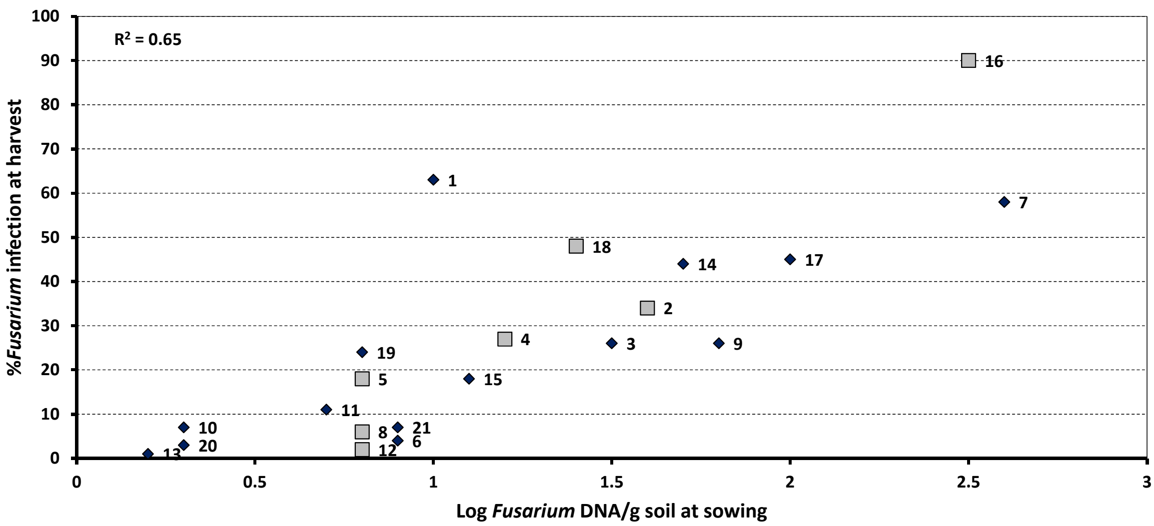


**Figure 1.** Relationship between at sowing DNA levels of Fusarium using PreDicta B® and incidence of crown rot infection at harvest – 'Unspiked' samples in 2013
Sites spiked with stubble represented by larger grey squares (sites 2, 4, 5, 8, 12, 16 and 18)

There was a 65% correlation between unspiked PreDicta B® results collected at sowing and the actual incidence of crown rot infection that developed by harvest (Figure 1). Fourteen sites in 2013 had a low or BDL risk for crown rot development based on unspiked PreDicta B® soil tests at sowing. At 8 of these sites (6, 8, 10, 11, 12, 13, 20 and 21) the DNA test correctly predicted the actual level of disease which developed while at 6 sites (1, 4, 5, 15, 18 and 19) PreDicta B® underestimated the risk of disease development. This is generally considered a 'failure to warn' and was particularly evident at site 1 (NVT Bellata) where only a 1.0 log *Fusarium* DNA value was measured at sowing but 63% of plants were infected with crown rot at harvest. In the medium risk category the DNA test correctly predicted the incidence of disease development at two sites (3 and 9) but underestimated the risk at two sites (2 and 14). All three sites predicted to be in the high risk category by the DNA test at sowing (sites 7, 16 and 17) did develop high infection levels during the 2013 season (Figure 1).

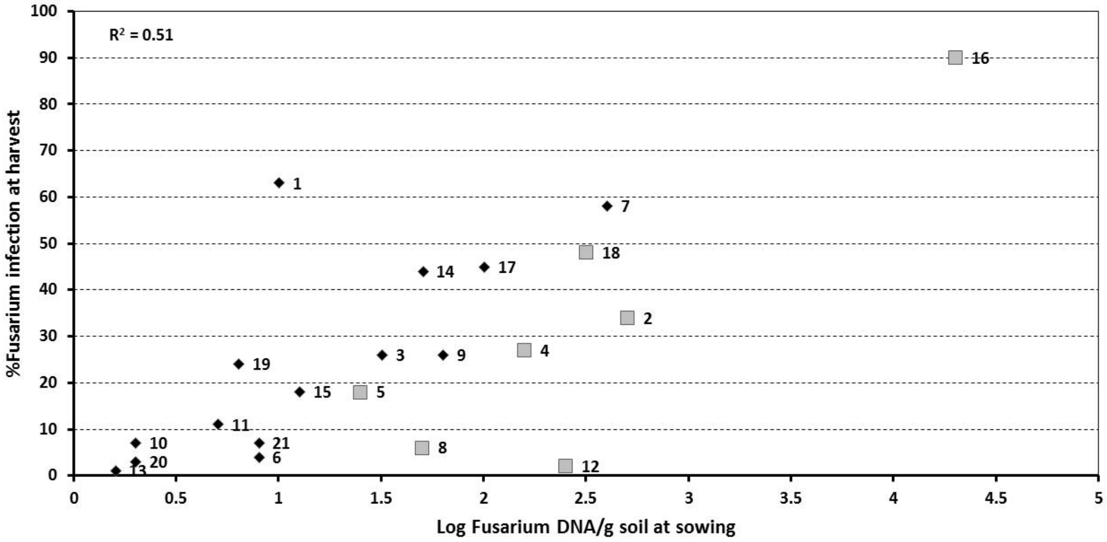


**Figure 2.** Effect of 'spiked' samples at 7 sites on the relationship between at sowing DNA levels of Fusarium using PreDicta B® and incidence of crown rot infection at harvest – 2013.
Sites spiked with stubble represented by larger grey squares (sites 2, 4, 5, 8, 12, 16 and 18)

The addition of stubble to the PreDicta B® soil samples ('spiking') collected from seven of the 21 sites at sowing reduced the correlation with the incidence of plants infected with crown rot at harvest down to 51% (Figure 2). However, spiking with stubble at sites 4, 5 and 18 removed them from the low risk category into their correct level of disease incidence at harvest. That is, these were no longer 'failure to warn' situations, with the stubble spiking correctly predicting the risk at sowing of what developed by harvest in the crop. Stubble spiking also corrected the underestimation of risk from medium to high at site 2. Spiking did not change risk categories at site 16 which was high with both the unspiked and spiked soil samples. However, the higher DNA level in the spiked sample better reflected the higher disease incidence (90%) at this site relative to other sites (max. 63%) in 2013.

Unfortunately, in two situations (sites 8 and 12) spiking led to an overestimation of the crown rot risk at sowing. Spiking pushed site 8 into a medium risk category but only 6% of plants were infected at harvest while site 12 was pushed into a high risk category with only 2% of plants infected at harvest. These situations would be considered false positives and potentially lead to a missed opportunity for growers where they could have grown a winter cereal crop with minimal risk of yield loss from crown rot.

**Conclusions**

PreDicta B® is a soil based test so with the collection of cores targeted at the previous winter cereal rows it can provide a good measure of *Fusarium* levels in the crowns below ground but is restricted in its ability to detect levels in above ground stubble. Adding stubble ('spiking') is likely to increase the overestimation of crown rot risk (false positives) while reducing the likelihood of underestimation or 'failure to warn' which we consider a preferred situation for growers.

The addition of stubble is also likely to reduce sampling issues following wetter summers (e.g. some northern regions in 2014/15) which can result in greater survival of *Fusarium* in above ground residues. Significant summer rainfall can lead to rapid decomposition of the crowns of previous cereal crops below ground which reduces the survival of *Fusarium* in this tissue. However, standing stubble dries out relatively quickly following rainfall events and can hence harbour crown rot inoculum for an extended period. Soil sampling, even targeted at the previous cereal row, will only detect *Fusarium* levels in the crowns. Hence, the addition of stubble to PreDicta B® soil tests will compensate for situations where there is still significant survival of *Fusarium* in above ground residues.

Recent collaborative research in the northern region between SARDI and NSW DPI has demonstrated that use of a smaller diameter (1 cm) soil core (e.g. Accucore) to collect 30-45 cores (depending on sampling depth) targeted at the previous cereal row if evident provides a good measure of both RLN and crown rot risk along with a range of other pathogens. This number of cores collected spatially across the paddock is required to account for the potential variability in the distribution of crown rot inoculum.

This research was continued across further sites in the northern region in 2014 and expanded to around 160 NVT sites nationally. This will facilitate further refinement of sampling strategies and calibrate risk categories across regions.

**Recommended PreDicta B® sampling strategy for crown rot**

These findings have resulted in amended sampling strategy recommendations to improve the value of PreDicta B® as a management tool for crown rot. To correctly sample, growers and advisors should:

- Collect three cores of 1 cm diameter and 15 cm deep from each of 15 different locations within the target paddock or production zone. Samples may be taken to 30 cm depth in the northern region if concerned about *Pratylenchus thornei* detection. If using a larger diameter core or coring to 30 cm, take fewer cores per location.
- Take the soil cores from along/in the rows of previous cereal crop if still visible and retain any stubble collected by the core (most soil borne pathogens are concentrated under the rows of the last cereal). Sampling depth (0-15 cm or 0-30 cm) does not appear to greatly impact on detection of the various pathogen levels in the northern region when the collection of cores is targeted at the previous cereal rows. However, the actual sampling depth needs to be recorded on the sample bag when collected as it is used to refine reporting of results to adjust for pathogens which are more concentrated at the soil surface.
- If the rows cannot be seen, take the cores at random.
- Add two piece of cereal stubble (if present) to the sample bag at each of the 15 sampling locations to improve the detection of crown rot. Each piece should be a single dominant tiller from the base of different plants and include the crown to the first node (discard material from above the first node).
- The maximum sample weight should not exceed 500 g.
- Significant stubble disturbance such as through harrowing, cultivation or mulching increases the risk of crown rot development if the stubble is infected with *Fusarium* and collection of soil samples prior to stubble disturbance is likely to underestimate the crown rot risk.

**Acknowledgments**

This project was co-funded by NSW DPI, SARDI and GRDC under the national improved molecular diagnostics for disease management project (DAS00137) and the national crown rot epidemiology and management program (DAN00175). Assistance provided by Robyn Shapland, Finn Fensbo, Patrick Mortell, Kay Warren, Tara Burns and Karen Cassin (NSW DPI); Herdina, Russell Burns, Aidan Thomson, Ina Dumitrescu, Danuta Pounsett, Irena Dadej, Daniele Giblot-Ducray (SARDI); and Diane Hartley (CSIRO) is greatly appreciated.

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# The what, where and why of soil testing in the northern region

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**Key words**

Soil testing, sampling frequency, sampling depths, crop responses

**GRDC code**

UQ00063, UQ00066

**Take home message**

Soil testing is a key component of ensuring both sustainable land management in the longer term and maximising the chance of reaching the water-limited yield potential in the coming season. The sampling strategy adopted will be determined by the reason for sampling (fertility monitoring or fertilizer diagnosis), the size and availability of the different pools nutrient in the soil (determining the appropriate laboratory test method), the mobility of the nutrients of concern in the soil profile (determining soil layers of interest) and the root activity of different rotation species in that soil type-seasonal rainfall combination.

The correct soil sampling strategy and diagnosis of potential nutrient limitations will not guarantee an economic response to applied fertilizer, as seasonal conditions and inappropriate application strategy (timing or placement) can reduce the crop nutrient requirement or limit crop recovery of the applied nutrient. However, it will ensure the best possible chance of delivering on water-limited yield potential in the coming season and represents value for money in a farm management plan.

This paper discusses current thinking on soil sampling methodology (frequency, depth intervals), analytical methods and interpretation relative to fertilizer N responsiveness for the northern grains region.

Perhaps the most compelling argument for soil testing is that if you don't understand the fertility status of the soils under management it is extremely difficult and time-consuming to then ensure the right fertilizer product, application rate, and method of application are used to maximise chances of crop recovery and an economic yield response. This is becoming increasingly important in the northern region as the native fertility levels in our once-fertile clay soils are diminished through grain removal and we become increasingly reliant on external nutrient inputs.

## Northern soils and climate

We have some clear advantages in our region over other rain-fed cropping zones. Firstly, moisture stored in the soil profile during a fallow can deliver a significant proportion of our annual crop growth and yield (especially in winter cropping), so once we make a planting decision the questions about crop size (and hence nutrient demand) are more about how much *extra* growth/yield we may derive from the seasonal forecast of in-crop rainfall rather than whether we will have any crop at all. Secondly, for expensive nutrients like phosphorus (P) and potassium (K), we find these nutrients have an excellent residual value for seasons following the actual application, so we have flexibility to apply these nutrients when our cash flow and seasonal/stubble conditions suit, rather than for each crop. Clearly once we understand the soil status of these nutrients, the different crop species nutrient requirements and the rates of crop removal in harvested produce, we can effectively use nutrient budgeting (fertilizer applied - grain removal) to guide our fertility strategy.

However our heavier soil types also confer some disadvantages, and these relate to the typically mobile nutrients like nitrogen (N – our largest and most expensive nutrient input) and sulphur (S). These nutrients are less mobile in clay soils, and while that means they are less likely to be lost below the root zone by leaching, they are also slower/require higher amounts of rainfall to redistribute into subsoils where much of crop root activity (water and nutrient uptake) occurs. In the case of N, this slow movement into the profile also increases the risk window for significant losses to the atmosphere as a gas through the processes of denitrification and volatilization. These processes predominantly occur at or near the soil surface, although in the case of denitrification, can also extend to deeper layers under prolonged wet conditions. These loss pathways can result in significant losses of plant-available N and so shift the soil nutrient status out of the normal expected range, with implications for fertilizer requirement in subsequent crop seasons. The only practical way to assess the outcome of 'unusual' rainfall events/seasonal conditions for these nutrients is soil testing.

**Soil testing strategies**

Soils can be tested for a range of factors - to estimate how much water can be or has been stored; to identify the depth of root barriers or subsoil constraints such as boron or salinity; or the potential occurrence of a soil-borne disease. In this paper we focus on soil testing in relation to crop nutrition. This testing can be undertaken to either monitor long term fertility trends in cropped fields (i.e. is my fertilizer strategy maintaining my soil available nutrient status, and are these still appropriate to address yield limitations) or to identify the fertilizer requirement for the coming season. The field sampling strategies to address these two objectives are quite different. The first is quite challenging in trying to quantify changes in nutrient status over time, through repeated sampling at the same and at the same (or similar) reference points, to minimize background variability. The second and most commonly applied approach is trying to adequately represent the fertility status across the management unit in question, be it a yield zone, soil type or paddock..

The frequency with which this sampling should be undertaken will be related to the nutrient status of the field (are levels marginal/limiting or is there good background fertility?) and also how quickly the nutrient status can change (in response to crop uptake and removal, or to rainfall events/seasonal conditions). It is important to remember that when interpreting soil test results the values on the report are (i) only as good as the paddock sampling strategy with which they were collected, (ii) have variability associated with the laboratory analysis and detection method, and (iii) are being related to a critical range of soil test values below which a crop response is expected. In other words, normal soil test results should be used as a guide rather than a guarantee, but will still provide a very firm plank in a sensible nutrient management program. Ideally, integrating plant tissue analysis also would provide a more robust assessment of the soil fertility status.

Sampling depths will vary with the nutrient and reflect the zones in the soil profile contributing to meeting crop demands. The most common soil sampling depth for nutrient analysis has been 0 to 10 centimetres for broad-acre crops. This layer was chosen because nutrients, especially P, and plant roots in early growth stages are more concentrated within this layer. However to obtain more comprehensive soil nutrient data, sampling below 10cm should be considered for some nutrients.

Suggested sampling increments for key nutrients (and salinity/sodicity constraints) for northern cropping regions are:

- 0 to 10cm (N, P, K,S and sodicity);
- 10 to 30cm (N, P, K and S);
- 30 to 60cm (N and S, salinity/sodicity);
- 60 to 90cm (N, salinity/sodicity); and
- 90 to 120cm (optional - N, salinity/sodicity).

Deeper sampling does raise issues of logistics and cost, which should be discussed with soil test providers. However, the additional information provides a clearer insight into nutrient status in the crop root zone. Changes in level of nutrient availability or subsoil constraint are very slow so the frequency with which these need to be measured also has longer time scale, amortizing the cost out over many years.

**Analytical results and testing methods**

Soil test information is most useful for indicating the available amounts of macro-nutrients (those required in relatively large amounts to sustain plant growth – N, P, K, and S, calcium [Ca], magnesium [Mg] and sodium [Na]). Results for micro-nutrients (zinc, copper, manganese, boron) are also useful, but much more as a broad indicator of soil status rather than being directly linked to crop requirements and likely fertilizer response. Tissue testing for micronutrients is typically more informative for plant requirement in that regard.

Appropriate soil tests for measuring soil extractable or plant available nutrients in the northern cropping region are:

- Bicarbonate extractable P (Colwell-P), to assess easily available soil P;
- Acid extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues;
- Exchangeable K;
- KCl-40 extractable S or MCP-S; and
- 2M KCl extractable mineral N, to provide measurement of nitrate-N and ammonium-N.

Tests for N and S provide information on nutrient supply (i.e. they can be directly linked to the quantity of nutrient available to the crop), while P and K tests indicate nutrient sufficiency/deficiency. It should be noted that N (and to a lesser extent S) demand is highly influenced by seasonal conditions, mineralisation from crop residues and soil organic matter between testing and harvest, and crop yield potential, making soil testing for N in isolation an unreliable indicator of fertiliser N requirements.

Other measurements that aid the interpretation of soil nutrient tests include:

- Soil carbon/organic matter content;
- Phosphorus buffering index (PBI);
- Soil salinity measured as electrical conductivity; and
- Chloride and other exchangeable cations (Ca, Mg and Na) including aluminium.

Further details of these analytical methods can be found in the Crop Nutrition factsheet for the northern grains region (http://grdc.com.au/Resources/Factsheets/2014/01/Soil-testing-for-crop-nutrition-North )

**Frequency of testing**

The frequency of soil testing in a field will be determined by the size of the available nutrient pool, the mobility of each nutrient in soil water and the rates of crop uptake and removal. The availability of nutrients which are accumulated and removed in large quantities (e.g. N), or which are subject to significant loss pathways (gaseous or leaching losses) can change quite quickly, and so will require closer attention. This may include regular soil testing, but under a string of similar climatic conditions, use of a nutrient budgeting approach combined with periodic soil testing can provide satisfactory results. However, as indicated by the problems with N availability after the La Nina years in 2010-2012, once anomalous events occur a soil test re-set is required to quantify the impact and identify the need to change the management approach.

Other nutrients taken up in large quantities but not necessarily removed in grain (e.g. K), and which are not mobile in the soil water, can change their distribution down a soil profile quite quickly, concentrating in shallow topsoil layers. Minimum or no-till management accentuates this nutrient 'stratification' so monitoring to detect such changes and develop a management response can be required relatively frequently in soils where (particularly subsoil) nutrient status is marginal.

Noting these exceptions, some general comments about frequency can be considered. Nutrient status in the top 10cm can typically change the fastest due to high root densities, stubble/residue return and fertilizer placement. As a result, these layers are typically sampled with greatest frequency. With the exception of mobile and dynamic nutrients like N, changes in status in deeper layers will be slower, especially in relation to immobile nutrients like P, K and micro-nutrients, and so will require less frequent testing. However an important point is that knowledge about the subsoil nutrient status of each paddock, especially in relation to slow release nutrient pools like BSES-P and limits to root activity like salinity, are essential to allow development of an effective fertilizer management program.

**Relating soil test results to likely fertilizer responses**

This topic was covered by Chris Guppy in some detail in the 2012 Goondiwindi Updates, and a detailed research program to improve our understanding of the critical soil test ranges below which crop response to applied fertilizer would be expected has been undertaken since then in UQ00063 (PKS in all crops) and UQ00066 (N in sorghum and canola). This work was based on the realization that most attention had been applied to wheat (N responses and the need for starter P based on the 0-10cm layer), with few guidelines for other crops. In the following section we show new information on the relationship between soil test and fertilizer N responsiveness (expressed as % maximum yield with applied N) for sorghum derived under UQ00066, and note that similar relationships have not yet been able to be developed for canola.

We also update (or in some cases simply reproduce) the indicative estimates of critical soil test ranges for P and K reported by Chris Guppy in 2012, and note that results from UQ00063 have yet to resolve the uncertainty around the ability of soil tests to predict responses to applied S – even in a supposedly responsive crop like canola.

*Soil test N response for sorghum*

The relationship for sorghum (Fig. 1) looks promising for all except low yielding crops, although surprisingly there is no clear indicator of different critical soil profile N contents (below which fertilizer responses are expected) for crops with different yield potentials and presumably N demands – although there are suggestions that lower yielding crops are less N limited when soil profile N at planting is <70-80 kg/ha in the top 120cm. The quantum of sorghum grain yield response to applied N (Fig. 2) increased as profile N reserves at sowing fell, with the rate of increase greater for sites and seasons where crop yield potential was high. These slopes are an indicator of the likely economic benefit of applied N.

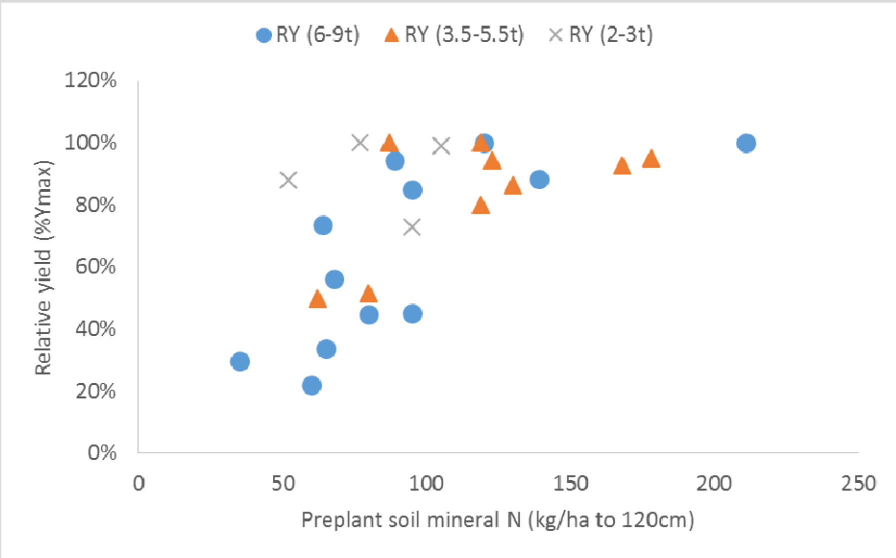


**Figure 1.** Relationship between relative sorghum grain yield (Y0/Ymax) and profile mineral N (sum of $NH_4$-N and $NO_3$-N) determined in soil tests taken prior to fertilizer application and crop sowing. Relationships are shown for soil profile depths of 120cm, with experiments with different seasonal yield potentials (2-3 t/ha, 3.5-5.5 t/ha and 6-9 t/ha) indicated by contrasting symbols.

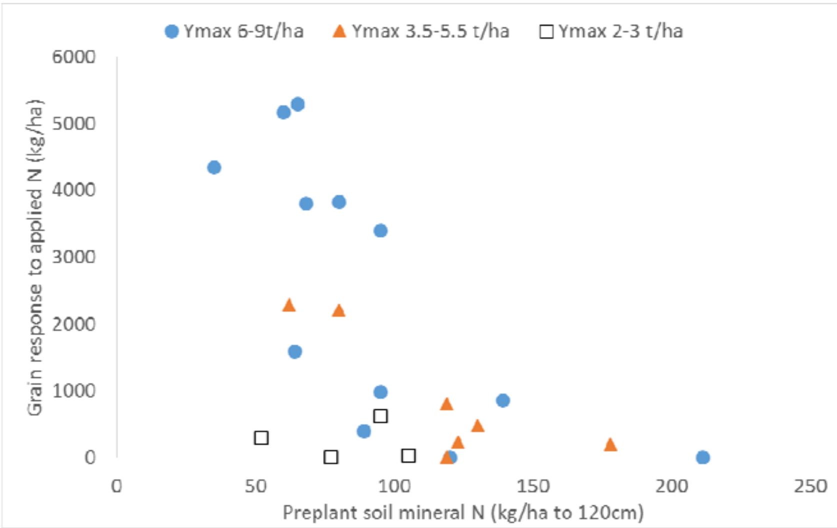


**Figure 2.** The quantum of sorghum grain yield response to applied N fertilizer (Ymax – Y0) plotted as a function of profile mineral N (120cm depth) at or prior to sowing. The steeper slope of the response surface in sites/seasons with a higher yield potential indicates greater returns on fertilizer N investment.

*Phosphorus soil tests*

The values listed below for P tests are what we currently use to determine if sites are likely to respond to P (starter P or deep bands), and it is a combination of the two distinct soil P test measurements that give the best indication of likely crop response. Colwell-P is measuring the labile, easily plant available P pool, whilst BSES-P measures not only this pool but also a pool that only releases P very slowly. The key difference is that this slow release pool will not release enough P fast enough to meet the demands of a rapidly growing crop, and so without some rapidly available Colwell P, addition of soluble P fertilizer is required.

**Table 1.** Generalised critical P values used to determine likely response or drivers of P availability in northern Vertosols

| | Surface (0-10cm) | | Subsoil (10-30cm) | |
|---|---|---|---|---|
| **Colwell P** | <25 mg/kg | Likely to get a response to starter P | <10 mg/kg | Likely to get a response to deep P placements |
| | >60 mg/kg | Ensure good groundcover to limit erosion risk! | >100 mg/kg | Unlikely to see P deficiency in your lifetime |
| **BSES P** | <25 mg/kg | Limited evidence of residual fertiliser accumulation | <30 mg/kg | Limited reserves of slowly available P. Consider replacement of removed P once every 5 years. |
| | >100 mg/kg | High residual fertiliser load | >100 mg/kg | Potential to slowly replace Colwell P reserves |

There are species variations in the critical Colwell values according to species planted. For example maize and wheat require between 25-30 mg Colwell P/kg in the 0-10cm layer, while peanuts require only 12-15 mg/kg, with limited responses above that value. Although we have placed 'critical values' in the surface BSES tests in Table 1, we pay very little attention to these values. We are actually content with Colwell and PBI tests in 0-10 and 10-30, and BSES in the 10-30 only, at least once. Because BSES-P releases only slowly, movement in that value takes years, so does not need to be monitored annually.

Because P is an element that roots have to grow towards to maintain uptake, anything that limits the active extension and proliferation of roots will necessarily limit the accessibility of the P that is, at least in a soil test, considered available. Hence, soil conditions that inhibit root growth (sodicity, pH, salinity, nematode damage), necessarily increase the critical values because higher soil solution P concentrations are needed to match demand from a smaller root system. Under these circumstances we would encourage test strips be laid down to determine if remediation is economic. We remain uncertain of the responsiveness of crops to intermediate soil P values, but would expect variation based on the moisture regime the crop experiences each year.

The lower *critical* values in the subsoil for available P (and available K, below) reflect the larger soil volumes in a 10-30cm depth increment. By the time a plant root system requires nutrients from these depths, many of the yield limits such as grain number have been established in response to early P status (starter P and 0-10cm P status). What is needed by the plant then through to maturity is a long, regular arrival of nutrients from a more extensive and established root system. Plants will only rely on the nutrient status in these subsoil levels when times are hard near the surface. Surface moisture conditions through a season determine the dependence on subsoil nutrient resources, and consequently responses to deep placement. The excellent residual value we have seen from deep P applications in trials in a number of sites suggests that deep P placement followed by a season where topsoil supply dominates does not represent a waste of money. That deep P will be available to subsequent crops in the rotation.

*Potassium soil tests*

Potassium availability is a little more difficult to establish rules of thumbs for, but Table 2 below summarises our current thinking. Again, there are species differences in these values too. For the majority of species these values are about where we think responses are likely, however, we know that cotton requires higher K availability and critical values in cotton can be almost twice those reported in Table 2.

**Table 2.** Critical K values used to determine likely response or drivers of K availability in northern Vertosols

| | Surface (0-10cm) | | Subsoil (10-30 cm) | |
|---|---|---|---|---|
| **CEC** | ExK (cmol/kg) | High Mg (>30% CEC) or Na (>6% CEC) | ExK (cmol/kg) | High Mg (>30% CEC) or Na (>6% CEC) |
| **<30 cmol/kg** | 0.2 | 0.4 | 0.1 | 0.2 |
| **30-60 cmol/kg** | 0.4 | 0.7 | 0.3 | 0.5 |
| **>60 cmol/kg** | 0.6 | 1.0 | 0.5 | 0.8 |

Considerably more work is required to improve the precision of these critical values, and to understand the mechanism behind the increase in those values where soil Na or Mg status is high. The two main mechanisms are direct competition at the root surface between these cations and K or changes in soil physical structure and aggregation that results in slower root extension and proliferation in the soil volume. It is highly likely that both are important in determining the availability of K to plants, but as yet we are only taking early steps in separating out these effects and understanding which plays a more significant role. Sorting out the importance of each of these mechanisms greatly affects how you manage them, as it will determine whether you attempt to broadcast K widely and enrich a much larger soil volume a little, or concentrate your K in multiple bands at various row spacing. The reason the critical value increases with CEC in Table 2 is because as the CEC of a soil increases, the buffer capacity of the soil for K increases along with it. In essence, the rate at which K is released from the soil to replace that taken up by a plant root is slower than the rate required by the plant root to maintain adequate K status, as the CEC increases. It is very similar to the way a high PBI in a soil increases the critical Colwell P value.

We are continuing to develop a method to estimate the slowly available reserves of K in each soil, with the tetra-phenyl borate extractable K (TBK) method still the most promising. A concerted push to develop testing methods for these slowly available pools is being undertaken by Chris Guppy (UNE) and Phil Moody (DSITI) in the next 3-4 years.

Through our current K field research, whole plant tissue K concentrations at maturity are emerging as a reasonable confirmation of soil K status.

*Sulfur soil tests*

Critical values for S responses in the surface are currently set at around 6 mg/kg of KCl-40 extractable S and in the subsoil, this would fall to around 4 mg/kg. However, we are currently recommending taking a deeper subsoil test for S, from 30-60cm depth. This is simply because S is far more mobile in the soil profile of heavier clay soils than either P or K, and hence, depending on rainfall, can move vertically in the soil column and be found at deeper depths. Responsiveness to S, where subsoil S is low, is also affected by soil moisture status. A dry topsoil, where organic S reserves accumulate, limits the mineralisation and release of S associated with that organic matter. Often a transient S deficiency can occur in prolonged dry periods, but is relieved with rainfall. At the very least, we are advocating monitoring S levels through the surface 60 cm.

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# Optimising sorghum profitability in Northern NSW – east and west of the Newell – an update of recent research

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**Key words**

grain sorghum , row configuration, plant population, hybrid

**GRDC code**

DAN00150 Sorghum in the western zone
DAN00195 Tactical Sorghum and Maize Agronomy

**Take home message**

- Early plant sorghum currently offers a more attractive proposition to growers than late plant sorghum, mostly for logistical and rotational reasons.
- Yields during the trial seasons 2010-2013 were generally more than 1.0 t/ha higher than the long term average for this region. In these seasons, yield declined as effective row spacing increased. Solid plant > single skip = super wide > double skip.
- Yields during the seasons 2013-2015 were lower yielding than the long term average. In these seasons, there was no significant difference in yield across row configurations for three of the five sites. At the lowest yielding (av. 0.74 t/ha) site, solid plant yielded significantly less than all other configurations. Across all 2010-2015 sites the average yields were 3.04 t/ha.
- Plant populations should be targeted in the realm of 30 – 50,000 plants/ha where the expected yield is 2.0 t/ha or greater. Where expected yields are less than 2.0 t/ha, plant populations as low as 15,000 plant/ha can provide slight improvements in yield compared to 30 and 50, 000 plants/ha.
- Hybrids should be selected which have a moderate to high level of tillering as this mechanism allows plants to respond to variable environmental conditions.

**Introduction**

Grain sorghum remains the main summer crop in the northern grains region, with northern NSW planting on average 160,000 ha. The main zones for sorghum production continue to be the area east of the Newell Highway and the Liverpool Plains in NSW.

NSW DPI, GRDC and Pacific Seeds partnered in a project focused on sorghum production west of the newell highway in NSW in 2010. This project “Sorghum in the western zone” was targeted at producing a data set from varying a range of agronomic factors in order to improve both the reliability and yield of sorghum in these areas where sorghum is not an established part of the rotation.  In the area west of the Newell Highway, sorghum production is variable in acreage as well as production tonnes. In an attempt to boost confidence in sorghum as a reliable summer cropping option by increasing the reliability and yields of sorghum a research project was commenced in the 2010-11 season targeting the matching of suitable hybrid types to optimum plant populations and row configurations. This research has led to a series of recommendations for the low- medium rainfall zone.

A second project “Tactical sorghum and maize agronomy” commenced in 2014-15 season, funded between GRDC and NSW DPI this project focuses on production in the areas east of the Moree and the Liverpool Plains in sorghum and maize, but with additional maize trials west of the newell highway as well.

The data presented in this paper is a compilation of the results of five years of research from the two projects, from trials conducted both east and west of Moree.

**Sorghum agronomy – getting the basics right**

A series of thirteen dryland trials have been conducted over five years; from 2010 – 2015 at sites primarily west of the Newell Highway, with one site east of the Newell in the 2014/15 season. Trials were located at; Mungindi, Morialta Junction, Rowena, Tulloona, Gurley, Garah, Bellata, Ashley, Bullarah and Terry Hie Hie. The trials were focused on establishing a data set around three primary factors; the optimum row configuration, plant population and hybrid to be used, although additional data was gathered from each site on issues such as crown rot, soil water and nitrogen use where possible.

The aim of this sorghum research is to minimise the risk of total crop failure but also increase yield potential for sorghum producers in this zone, four primary areas are discussed in this section of the paper; sowing time, plant population, row configuration and hybrid type selection.

*Sowing time*

Eight of these trials were planted in the early planting window, between September and October and five of these trials were planted in the late planting window of January. The five late plant trials were in the 2012/13 and 2014/15 growing season.

Average yields from the eight early plant trials ranged from 4.53 t/ha down to 0.74 t/ha. In comparison yields from the five late planted trials, ranged from 4.30 t/ha down to 1.59 t/ha.

While it is not possible to draw firm conclusions on which planting time is preferred from this data set ( long term modelling would assist), as there has been very little difference in yield, it is suggested that early plant sorghum (Sept/ October) has been a better fit within the farming system than late plant sorghum.

Early plant sorghum, typically sown in September / October is intended to escape the summer heat at flowering; as well as splitting the labour/ equipment requirements more evenly across the year so winter crop planting and summer crop harvest do not coincide. Early planted sorghum is also typically harvested while conditions are still warm meaning a quick dry down time, no grain drying and harvest before the pressures of winter planting. The early harvest timing also allows the option of a double crop back into chickpeas or a winter cereal should sufficient rainfall occur to fill the profile sufficiently, thus expediting the move back into a winter cropping sequence. On the downside, cool soil temperatures with the early planting time can slow early growth and sometimes affect establishment.

Late planted sorghum typically avoids the heat at flowering, but is planted into high soil temperatures which rapidly dry out the seedbed. In addition most growers in this western zone are unwilling to let an early planting opportunity pass them by in case there is not another opportunity to plant.  Late plant sorghum also comes with the risk of cool temperatures during flowering and sorghum ergot. Late planting also means late harvest where dry down may be slow and difficult due to high grain moisture resulting in the need to dry sorghum as well as the crossover with winter planting causing additional demands on labour and machinery. Late planted sorghum also usually means the need to either short fallow to another summer crop or long fallow to the next winter crop, reducing the cropping frequency and subsequent cash flow.

Currently the case for or against early or late sowing time is largely based on the impacts on the farming system as there is insufficient data to build a more robust case on the impact on crop yield.

Crop modelling has provided simulated data across multiple years and seasons which suggests late planted sorghum to be the more reliable.

*Hybrid selection*

In this research three hybrid types were selected with diverse plant characteristics. Our aim was to compare hybrids with varying levels of tillering and staygreen. The three hybrids selected and their characteristics were:

1. Low tillering, High staygreen – 2436 and LT10 (both experimental lines) and MR Apollo
2. Moderate tillering, moderate staygreen – MR 43
3. High tillering, low staygreen – MR Bazley

In these trials, across all sites and seasons, on average, the hybrids with moderate to high levels of tillering have produced higher yields. In these trials the hybrids MR Bazley and MR 43 have been higher yielding than 2436, LT10 or MR Apollo by on average 0.35 t/ha (Table 1). The full potential of stay green as a plant characteristic has not been seen in this research either as the majority of seasons had higher than average yields or the pre-anthesis stress did not occur.

The general conclusion has been that hybrids with a low level of tillering have not been able to respond to the variable seasonal conditions by producing additional tillers (which equates to more heads) to capture additional yield potential unlike the hybrids with moderate to high levels of tillering, in this case MR 43 and MR Bazley. There has been very little difference in the grain yields of the moderate and high tillering hybrids at most sites where significant differences have occurred.

*Row configuration*

The most common row configuration in the western zone was double skip until recent years where there has been more interest in the 1.5m super wide row configuration. In contrast the area east of the Newell has been dominated by a solid plant configuration.

Four row configurations were used at the trial sites; a 1.0 m solid plant, single skip, double skip and a super wide (1.5 m solid) with the exception of Byra in the 2012/13 season which was on raised beds so a 2.0 m solid plant was substituted for a super wide configuration and Terry Hie Hie in the 2014/15 season where a narrower 0.75m solid plant was included.

Across these thirteen trials, where site yields were greater than 1.0 t/ha, the yields declined as effective row spacing increased, hence solid > single skip = super wide > double skip. At only one site; Ashley 2014/15; where yields were below 1.0 t/ha for all configurations, was the solid plant significantly lower yielding than all other configurations.

The solid plant configuration produced the highest yields, on average 3.54 t/ha, compared to 3.02 and 2.97 t/ha for single skip and super wide respectively and 2.42 t/ha for double skip. The 2.0 m solid plant treatment averaged 3.13 t/ha at Byra and the 0.75m solid at Terry Hie Hie yielded 4.38 t/ha. This equates to solid (1.0m) plant yielding 15-16 % more than the single skip or super wide and 32% more than the double skip.

The average yield of these sites was 3.04 t/ha which is around 0.5 t/ha higher than the long term average for grain sorghum in the North West NSW at 2.49 t/ha (NSW DPI Grains Report 1992-2012). This reinforces that the majority of the sites have been conducted in seasons which are more favourable than is the norm for this environment.

The data supports two conclusions, firstly that in above average seasons the solid plant configuration will always yield the highest, however it also comes with a greater risk of total crop failure in the low yielding seasons. Secondly that double skip configurations sacrifice significant yield potential but are inherently a safer option as they store more water in the “skip” area for use during grain fill.

Overall, to date it seems that single skip or the super wide configurations are the preferred options for growers in this zone as they offer a safer option in the dry seasons, and higher yields than the double skip, reducing the overall risk of growing sorghum in these environments.

*Plant population*

Over the research period four plant populations were targeted; 15, 30, 50 and 70,000 plants/ha; but only three populations were trialled at each trial site. The 30 and 50,000 plants/ha treatments were included in all trials.

In the 2010/11 and 2011/12 seasons there was no statistical difference between the yields from the 50 and 70,000 plants/ha treatments; which both produced the highest yields; as such the 70,000 population was dropped from the treatment set as it incurred additional seed costs for growers without providing additional return.

The 15,000 plants/ha treatment was added as “how low can we go?” a common question from growers and advisors. From this research the 15,000 treatment has always yielded lower than the 30 and 50,000 plants/ha except where the average site yield was less than 1.6 t/ha. At the two sites where average yields were less than 1.6 t/ha, the 15,000 plants/ha treatment yielded significantly more than the 30 and 50,000 plants/ha treatments.

It should be noted though that establishing a uniform plant stand with a target plant population of 15,000 plants/ha commercially is a lot more difficult with air seeders, the more common planter in the western zone for sowing sorghum.

Average yields of the thirteen trial sites showed an increase of 1.55 t/ha as plant population increased from 15 to 70,000 plants/ha. However there were few significant differences between the 30 and 50,000 plants/ha treatments.

**Conclusions**

In order to minimise risk and optimise yield in grain sorghum in the low- medium rainfall zone there is a greater emphasis on matching agronomic management to the environment than there is in hybrid selection.

Certainly hybrids have a role to play based on their suitability for environmental conditions and the relevant plasticity of their characteristics such as tillering, however in the trials conducted across both projects to date, the genetic potential of the hybrid has rarely been the limiting factor.

Currently the recommendations for sorghum in this zone, is to plant as early as possible, selecting either a single skip or super wide configuration and establish an even population of between 30 – 50,000 plants/ha using a hybrid with some level of tillering. An additional season of trial data is planned for this coming season, 2015/16 and will hopefully provide the final conclusions to the main management decisions for sorghum growers in this region.

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**Table 1.** Impact of hybrid type on yield (t/ha) in 2010-2015

| Hybrid Type | Site/ hybrid | Gurley 1011 | Mungindi 1011 | Rowena 1011 | Morialta 1112 | Rowen a 1112 | Bullarah 1213 | Byra 1213 | Gurley 1213 | Tulloona 1314 | Ashley 1415 | Gurley 1415 | Bellata 1415 | Terry Hie Hie 1415 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low tillering, high staygreen** | **2436** | - | - | - | 3.32 | 4.13c | 3.71b | 3.89 | 3.09b | 0.80c | | - | - | - |
| | **LT10** | 3.31 | 3.58c | 2.59b | - | - | - | - | | - | | - | | - |
| | **MR Apollo** | | | | | | | | | - | 0.76 | 2.11 | 1.41b | 3.75 |
| **Mod. tillering, mod. staygreen** | **MR 43** | 3.81 | 4.63a | 3.05a | 3.24 | 4.62b | 4.63a | 3.91<br>- | 3.80a | 1.00b<br>- | 0.71 | 2.22<br>- | 1.64a | 4.00 |
| **High tillering, low staygreen** | **MR Bazley** | 3.81 | 4.47ab | 2.46b | 3.34 | 4.81a | 4.61a | 3.77 | 3.67a | 1.32a | 0.76 | 2.10 | 1.73a | 3.74 |
| | *CV%* | *n.s.d* | *10.6* | *25.8* | *n.s.d* | *7.2* | *12* | *n.s.d* | *19.2* | *16.1* | *n.s.d* | *n.s.d* | *14.7* | *14.2* |
| | *L.s.d.* | *n.s.d* | *0.20* | *0.33* | *n.s.d* | *0.16* | *0.25* | *n.s.d.* | *0.32* | *0.08* | *n.s.d* | *n.s.d* | *0.12* | *n.s.d* |

**Table 2.** Effect of row configuration on yield (t/ha) in 2010-2015

| Site/<br>Row Configuration | Gurley 1011 | Mungin di 1011 | Rowena 1011 | Morialt a 1112 | Rowena 1112 | Bullarah 1213 | Byra 1213 | Gurley 1213 | Tulloon a 1314 | Ashley 1415 | Gurley 1415 | Bellata 1415 | Terry Hie Hie 1415 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Solid (0.75m)** | - | - | - | - | - | - | - | - | - | - | - | - | 4.38a |
| **Solid (1.0m)** | 4.58a | 5.38a | 3.22a | 3.47 | 5.24a | 5.29a | 5.29a | 4.46a | 1.04 | 0.58b | 1.87 | 1.55 | 3.94b |
| **Single Skip** | 3.52b | 4.28b | 2.63b | 3.42 | 4.59b | 4.22c | 4.26b | 3.33bc | 1.07 | 0.74a | 2.24 | 1.52 | 3.41c |
| **Superwide (1.5m)** | | 3.84bc | 2.88ab | 3.83 | 4.73b | 4.42b | 3.13c* | 3.64ab | 1.02 | 0.78a | 2.27 | 1.75 | 3.60bc |
| **Double Skip** - | 2.83c | 3.41c | 2.08c | 2.48 | 3.52c | 3.32d | 2.75c | 2.64c | 1.04 | 0.87a | 2.19 | 1.60 | |
| *CV %* | *11.6* | *10.2* | *25.8* | *18.3* | *7.2* | *12.0* | *13.6* | *19.2* | *16.1* | *15.8* | *19.8* | *14.7* | *14.2* |
| *L.s.d* | *0.52* | *0.78* | *0.38* | *n.s.d* | *0.37* | *0.17* | *0.55* | *0.96* | *n.s.d* | *0.16* | *n.s.d* | *n.s.d-* | *0.37* |

* Due to the trial being sown on raised beds, it was not possible to sow a 1.5 super wide treatments, so this was replaced with a 2.0m solid plant treatment.

**Table 3.** Effect of plant population on yield (t/ha) in 2010-2015

| **Site/ Plant Population** | **Gurley 1011** | **Mungindi 1011** | **Rowena 1011** | **Morialta 1112** | **Rowena 1112** | **Bullarah 1213** | **Byra 1213** | **Gurley 1213** | **Tulloona 1314** | **Ashley 1415** | **Gurley 1415** | **Bellata 1415** | **Terry Hie Hie 1415** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15,000** | - | - | - | - | - | 4.15 | 3.66b | 3.25b | 1.05 | 0.87a | 1.97b | 1.83a | |
| **30,000** | 3.48 | 3.99 | 2.82a | 2.56b | 4.40 | 4.39 | 3.90a | 3.60a | 1.02 | 0.71b | 2.13ab | 1.62b | 3.89 |
| **50,000** | 3.70 | 4.28 | 2.75ab | 3.48a | 4.60 | 4.40 | 4.01a | 3.70a | 1.05 | 0.65c | 2.33a | 1.33c | 3.85 |
| **70,000** | 3.75 | 4.41 | 2.53b | 3.87a | 4.58 | - | - | | | - | | - | 3.76 |
| *CV%* | *12.0* | *10.6* | *25.8* | *18.3* | *7.2* | *12* | *13.6* | *19.2* | *16.1* | *15.8* | *19.8* | *14.7* | *14.2* |
| *L.s.d.* | *n.s.d* | *n.s.d* | *0.22* | *0.61* | *n.s.d* | *n.s.d* | *0.21* | *0.29* | *n.s.d* | *0.05* | *0.22* | *0.15* | *n.s.d* |

# Grain Sorghum: Varietal reactions to heat stress and environment – what are they and why the differences?

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**Key words**

sorghum, climate risk, yield, sowing date, high temperature, pollen sterility, seed set

**GRDC code**

UQ00065

**Take home messages**

- Sorghum seed set is reduced by high temperature effects (>36-38$^{o}$C) on pollen around flowering
- Sorghum genotypes differ in their tolerance to high temperature stress
- Risk of high temperature damage depends on sowing date and variety
- Climate change will exacerbate high temperature effects but avoidance by crop management and genetic tolerance seems possible
- While late plantings (mid Jan) in NNSW avoid heat, late cultivars sown at this time have increased risk of cold conditions that reduce grain yield, and exposure to weather that may favour ergot.

## Introduction

Varietal attributes, such as heat stress tolerance, tillering, and maturity can all have large effects on yield. However, this will depend on starting soil water, time of sowing, crop management, and the nature of the season.

There are two things that are for sure –

1. we do **not** know what the yield outcome will be at the time of sowing, and
2. the superiority of specific genotype and management combinations varies from year-to-year depending on how the season transpires.

The best we can do is to estimate the risks of what might happen for different scenarios given historical climate data. The APSIM model provides the best technology for doing this and the sorghum model has been recently updated to incorporate the latest scientific knowledge on the physiology of crop growth and development (Hammer et al., 2010). We can now simulate risks associated with changes in genetics (G) and management (M) across environments (E) – the G*M*E landscape - with increased confidence by using the model with historical climate records (or with climate change scenarios).

Here we look at specific varietal attributes associated with heat stress tolerance and how they might affect yield outcomes. Recent research on high temperature tolerance is summarised and its implications for production risks evaluated by a crop simulation analysis.

For N NSW, late plantings can also risk exposure to low temperatures that affect pollen fertility and can favour the development of ergot.

**High temperature effects on sorghum**

We have recently conducted a range of controlled environment and field experiments to study the physiology and genetics of high temperature effects on growth and development of sorghum.

- Controlled environment experiment on varietal reactions to high temperature stress - 24 diverse genotypes were grown without water limitation at four day/night temperatures ranging from of 30/22° (standard) to 38/22° (high) for their whole life cycle.
- Controlled environment experiment on timing of high temperature effect - a tolerant and susceptible genotype were grown under either standard or high temperature for their whole life cycle except for 5 days when they were trnsferred to the other temperature
- Field experiment to validate effects in controlled environment – a selection of genotypes were grown in the field either with/without specifically designed covers that raised daytime maximum temperature by about 6°C.

High temperature conditions affected both vegetative and reproductive growth of the sorghum genotypes. High temperature increased development rate (i.e. shorter time to flowering), leaf number, and leaf appearance rate, but had no effect on leaf size. However, there was significant reduction in plant height, pollen viability and seed set under high temperature (Fig .1). There was significant variability in seed set and pollen viability responses among sorghum genotypes (Fig. 2) (Singh et al., 2015). The most tolerant genotypes showed only small reduction in seed set at 38°C, whereas the most susceptible showed significant reductions at 36°C. Seed set was highly correlated with pollen viability. All treatments were well-watered so this effect of high temperature on seed set is independent of the effect of moisture stress.


**Figure 1.** Effect of high temperature on seed set of B923296 (left panel) and contrasting effect for genotype 85G56 (right panel)

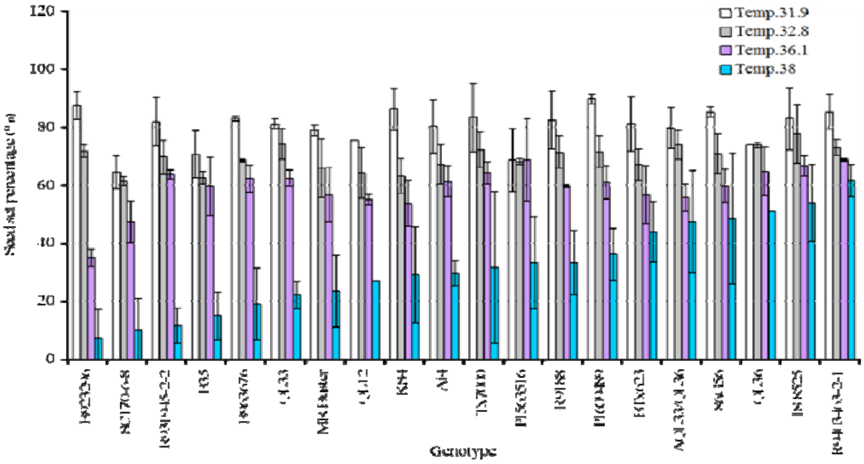


**Figure 2.** Effect of a range of high temperature treatments on seed set percentage for a diverse set of sorghum genotypes.

This evidence and that from other studies (Prasad et al., 2006) indicated that the effect of high temperature on seed set was most likely related to effects on pollen and thus likely occurred during the period of pollen formation or pollination. This was confirmed in the temperature switching experiment, which showed the effect occurred over about a 10-day period centred on flowering.

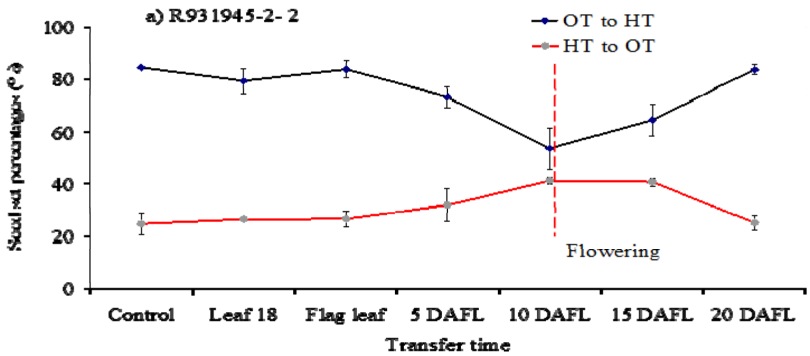


**Figure 3.** Effect on seed set of moving a susceptible cultivar from either Optimum Temperature to High Temperature (OT-HT) or the reverse (HT-OT) for 5-day intervals commencing prior to flag leaf full expansion. The control represents results without transfer.

We used this information to develop an index of the effects of genotype and high temperature on seed set that could be implemented in simulation studies.

**Low temperature effects on fertility**

There is little recent data on the effects of low temperature on sterility. An older paper on this topic found that during the period from a little before flag leaf appearance to grain set, multiple days of temperatures of less than 13°C would reduce seed fertility (Fig. 4). The effect comes in after 4 to 5 days of less than 13°C and more than two weeks of these conditions will reduce fertility to near zero.

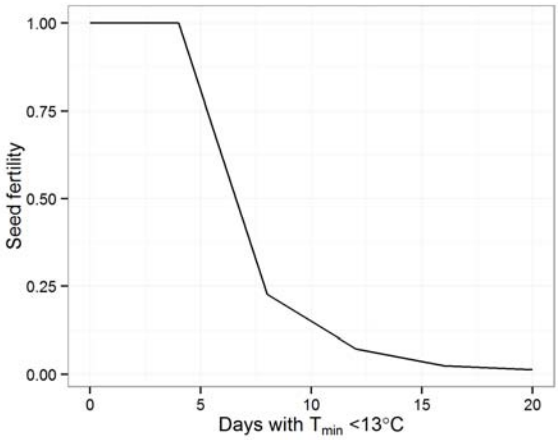


**Figure 4**. Effect on seed fertility of low night temperatures (from Downes and Marshall 1971).

**Implications of varietal reactions to heat stress on yield**

We simulated a range of sowing dates (Sept-Jan) at Moree for a standard medium-late maturity sorghum hybrid grown in 1m rows at 50,000 plants/ha on a 150cm deep grey clay soil with water-holding capacity of 285 mm. 50 years of historical climate data (from 1960) was used to simulate yield of crops assuming the same sowing date and starting soil water each year so that the only variable was the seasonal weather (Fig. 5). Simulations were conducted assuming that the profile held 100mm available water at sowing. In the initial set of simulations, the index representing the effect of high temperature on seed set was not invoked.

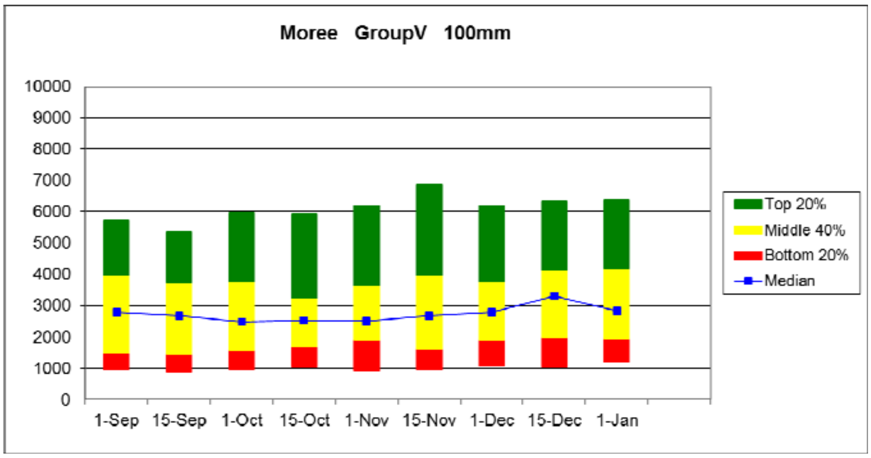


**Figure 5.** Yield (kg/ha) likelihood versus sowing date at Moree assuming 100mm available water at sowing. The blue line joins the median (50/50) yield and the bars indicate the range of yield in 80% of years. The best and worst 10% are not included. The 80% of years are broken into the best 20% (top-green), middle 40% (yellow), and worst 20% (bottom-red) of those years.

These results reflect the seasonal patterns of water availability to the crop via rainfall and evaporative demand patterns. With 100 mm water availability at sowing, in-crop rainfall and evaporative demand becomes important. While there is not a large effect of sowing date on yield likelihood, later sowings (Dec) gain a slight advantage at the median. However, these effects must also be considered in conjunction with timing of planting opportunities and cropping system issues.

How are these yield likelihoods affected by incidence of high temperature conditions? The historical climate data was first analysed to examine the frequency and timing of high temperature events in relation to the crop cycle associated with different sowing dates. Then simulations were repeated with the indices of the effect of high temperature on seed set invoked to estimate effects on yield.

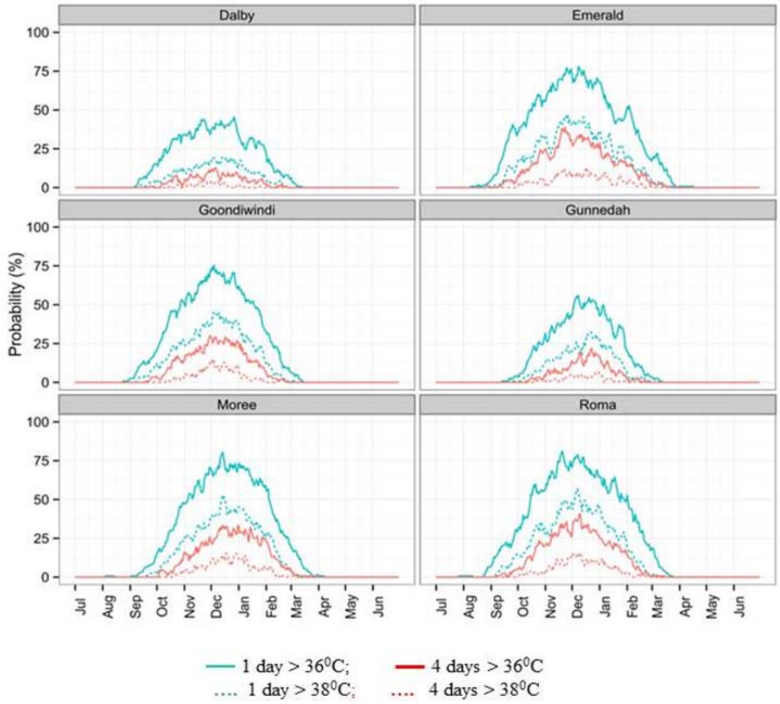


**Figure 6.** Probability of occurrence of either one or four days with a maximum temperature exceeding 36 or 38˚C within an interval of 200˚Cd (10-14 days) commencing at various times of year for key locations in the sorghum cropping region of NE Australia.

The frequency of occurrence in any 10-14 day period of days with maximum temperature >38C is greatest from mid-December until mid- January (Fig. 6). While there are many occasions at Moree (approx 50%) with at least one such day in the 10-14 day period, there are few (approx 10%) with more than 4 days. The effect on pollen viability, seed set, and hence yield, depends on the magnitude of the temperature event and its duration during the critical developmental window of this duration (10-14 days) around flowering.

At Moree, sowings during October will reach flowering at the high risk period for high temperature incidence (data not shown). There will remain some, but lesser, risk for earlier and later sowings. However, as high temperature occurrences can occur over a wide time frame during summer, other sowing times are not totally immune.

The simulated yield reductions due to high temperature effects on pollen viability and seed set varied considerably from year-to-year for a 1 Oct sowing at Moree with a susceptible genotype (Fig. 7). There were many years with more than 10% yield reduction (i.e. relative yield < 0.9), and 8 years out of 50 had severe effects (i.e. relative yield < 0.7). However, for a heat tolerant genotype there were no years with more than 10% yield reduction.

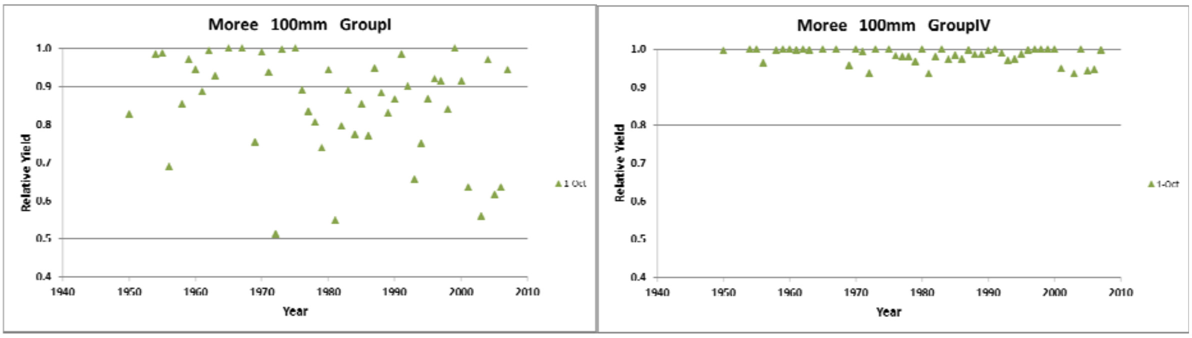


**Figure 7.** Relative reduction in simulated yield due to high temperature effects for 1 October sowing at Moree with 100mm available soil water with either a susceptible (Group 1 - left panel) or tolerant (Group IV- right panel) genotype

It is plausible to reduce high temperature risks through changing sowing date. At Moree, early (Sept) and late (Nov-Dec) sowings have lower risk on average than sowings in Oct-Nov (Fig. 8), but there are instances of severe effects (i.e. relative yield < 0.7) for all sowing times, except very late sowing (Jan). Hence, the simulations suggest management of sowing time to be a much less effective strategy in moderating high temperature risks than genetic modification. It is also considerably more difficult to implement as there is limited opportunity to control sowing time and cropping system issues (e.g. weed and disease control, rotation opportunities) restrict options.

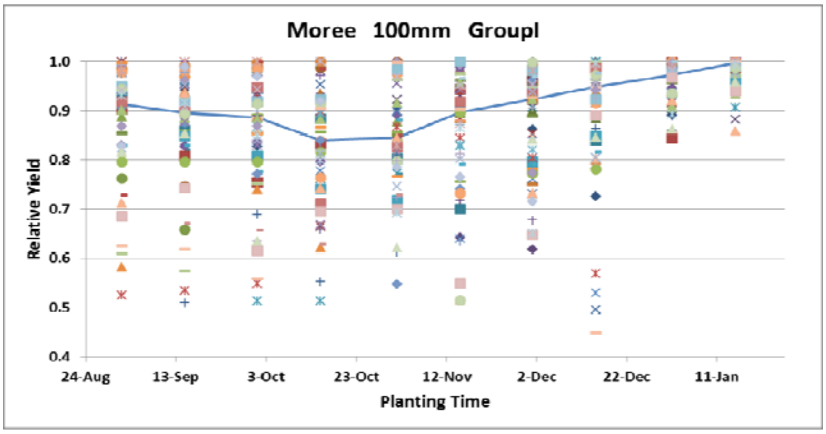


**Figure 8.** Relative reduction in simulated yield due to high temperature versus sowing date at Moree for a susceptible sorghum genotype. Each point represents the relative yield for one year of the 50-year simulation and the line connects the median relative yield for each simulated sowing date.

A final point to consider for Moree and other locations in N NSW, is that late summer plantings have potentially higher exposure to cold (Fig. 9). For a late maturing cultivar, planted Jan 15, the median anthesis date is about 79 days after sowing, (1st week of April), and in 1 in 4 years, this cultivar would be exposed to a damaging level of low temperature (5 days < 13°C) which could kill sufficient pollen to reduce yields by about 25% - similar to the heat effect for October plantings (Fig. 9a). For both dates, medium maturing cultivars would avoid these conditions in most years (< 10% risk). However, late maturing cultivars would be at risk of about 25% grain loss due to pollen sterility in 1 in 5 years for 1 Jan sowing and 1 in 2 years for a 15 Jan sowing, i.e. late planting of a late cultivar in this region carries about the same risk of similar yield loss (due to cold) as does an Oct planting due to heat.
In wetter years, ergot risks would also be increased as they are also associated with these levels of cooler temperatures.

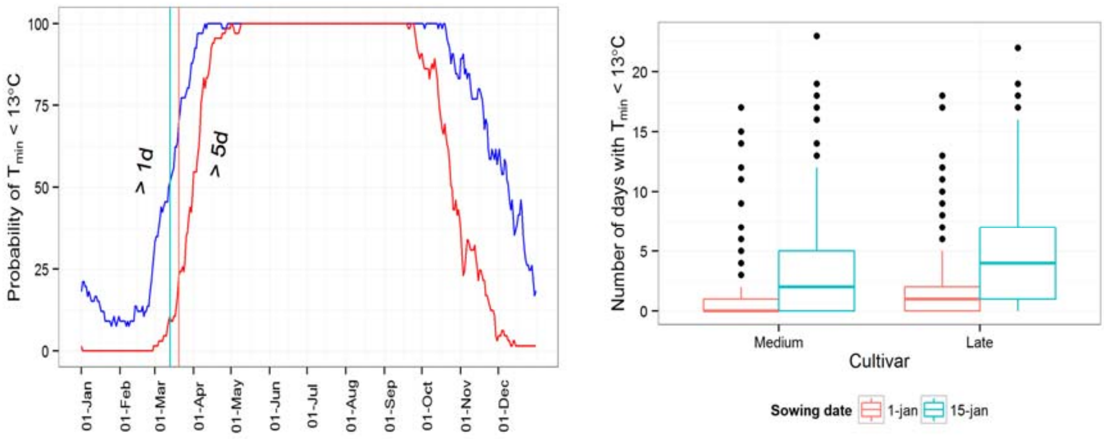


**Figure 9.** (a) Risks of greater than 1 or 5 days with Tmin < 13°C for any time of year in Moree with vertical lines indicating the median anthesis date of a medium or late maturing cultivar sown 15 Jan. (b) The number of days with Tmin < 13°C for a medium or late cultivar sown 1 Jan or 15 Jan.

**Conclusion**

The heat tolerance issue will be exacerbated as temperatures rise with climate change. The frequencies and severity of high temperature events are predicted to increase over the next decades (IPCC, 2007). It is clear that risks of yield reduction due to high temperature effects will increase. Our studies to date have identified potential sources of genetic tolerance to high temperature effects so that breeding options will be possible. However, it will be important to progress this work to install this level of genetic tolerance into elite sorghum germplasm, while seeking new sources in order to keep ahead of climate change. Interactions with management options, such as sowing date, will become more critical as risks increase.

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# Northern farming systems performance: can it be improved?

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**Key words**

Crop rotation, sequence, efficiency, system, economics

**GRDC codes**

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**Take home message**

- GRDC is investing in research aimed at understanding how the performance of current farming systems can be improved.
- Systems with different crop intensity (or frequency), crop sequences, system inputs and practices aimed at maintaining long-term soil resources are being compared experimentally.
- System modifications and their interactions of these various modifications are being examined at a core experiment site on the Eastern Darling downs, and 6 regional sites across the northern region are examining locally relevant system modifications.
- Experimental data and modelling are being used to assess changes and effects of the different farming systems on several attributes (e.g. water use efficiency, nutrient use efficiency, soil resource, pathogen and weed populations).

**Rationale**

Recent analysis suggests that there is potential to increase the efficiency of current farming systems. An analysis of surveyed crop sequences found that only 29% were achieving 80% of their potential water use efficiency. Similarly farming systems are facing emerging challenges of increasing herbicide resistance, declining soil fertility and increasing soil-borne pathogens all which require responses in farming systems in order to maintain system productivity.

The northern farming systems initiative aims to address these emerging challenges by investigating the question: Can systems performance be improved by modifying our farming systems?

The research aims to deliver information on the following issues:

- Key issues or areas where current systems are underperforming
- Benchmarks for, and gaps between, current and potential system water use efficiency (not just crop water-use-efficiency)
- What changes in farming systems enable further increases in system efficiency
- Benefits and costs of crop choices on various aspects of farming systems (water, nutrients, weeds, pests)
- Identify any possible future issues that are likely to arise in response to changes in farming systems

### Experimental plans

The northern farming systems initiative will implement a co-ordinated experimental program to examine a range of modifications to farming systems and quantify their relative impact on a range of measures of system performance. These modifications have been chosen following consultations with growers, advisors and other researchers across the northern region and are targeted to address apparent current and emerging challenges to farming systems. The range of systems have been chosen to capture the range of possible cropping systems operating in the northern region.

The combined experimental program will consist of 1 core site located at Pampas on the Eastern Darling Downs and 6 regional sites located at Emerald Agricultural College (Central Queensland), Billa Billa (Western Downs/Border Rivers), Mungundi (Western NSW and Qld), Plant Breeding Institute, Narrabri (Northern NSW), Nowley Research Station, Spring Ridge (Liverpool Plains), and Trangie Research Station (Central West NSW).

The core site will compare 34 farming systems (see Table 1). These include 8 summer crop dominated systems, 8 winter crop dominated systems, 14 mixed summer-winter crop systems and 4 systems involving ley pastures. The cropping systems (not ley pasture systems) involve factorial combinations involving different crop intensity (i.e. the number of crops sown/yr), crop sequences (including the range of crops grown) and nutrient supply/balance. Each of these systems are based on differences in key decision points or rules which aim to bring about these distinct changes in the farming systems. The systems tested at the core site are common with systems being tested in the regional experimental sites.

At each regional site a 'benchmark' system, based on current decision rules used in the district, will be compared with a common set of 4 individual system modifications (i.e. higher crop intensity, higher crop diversity, high nutrient supply and high legume frequency) (see Table 2). Additional regionally relevant modifications to systems may also be included based on local demand for these treatments. Table 2 summarises the common set and different modifications to be tested at each region and the equivalent system in the core site.

### Key metrics of systems performance

Over the life of the project each experimental farming system will be compared in terms of several attributes:

- Total grain production and quality
- Economics (inputs and returns)
- Efficiency of use of water and nutrients,
- Changes in soil nutrient stocks and soil health indicators
- Dynamics and populations of soil pathogens and weed populations

Together this information will be used to assess the relative performance of the farming systems against several metrics. This will help us understand the strengths, weaknesses and identify any future risks associated with particular system modifications.

### Systems modelling and analysis

A combination of several modelling approaches will be used in the project to examine the performance of current farming systems across the northern region. These models will provide predictions of the likely effects of the various systems modifications over the time and extrapolate experimental information to compare system performance under a range of climatic conditions and predict the implications at other locations and/or other combinations of systems (e.g. different sequences of crops) across the northern region. In particular, the simulation modelling will enable climate and price risk factors to be analysed for each of the systems.

**Table 1.** List of key modification foci for changes to farming systems, their associated rationale and impacts and how the characteristics or decisions would be altered to achieve the desired outcome. System treatments in italics are those that make up the current 'benchmark' system; System treatments denoted with a ^ are included in a full factorial at the core site and denoted with a # are only singular treatments or partial factorials at the core site.

| # | System modifications | Strategy | Anticipated impacts | Key characteristics & decision point change |
|---|---|---|---|---|
| **1.** | **CROP INTENSITY** | | | |
| *1A* | *Moderate crop intensity ^* | *Sowing on a conservative PAW threshold* | | *Higher PAW requirement to trigger a crop sowing event (e.g. 150 mm)* |
| 1B | High crop intensity ^ | Increase the frequency of crops sown in order to maximise proportion of rainfall transpired by crops | - Reduced fallow herbicide use<br>- Increased C inputs & soil OC<br>- Increased soil biological activity & nutrient cycling<br>- Reduce losses of water during fallows | Lower PAW requirement to trigger a crop sowing event (e.g. 75 mm) |
| 1C | Low crop # intensity | Reduce the risk for a particular crop by maximising soil water at sowing by proceeding with a long fallow period. | - Greatly reduced number of crops<br>- Higher profitability per crop<br>- Long fallow periods requiring large herbicide program and low ground cover risks | Crops only sown when very high PAW or full profile<br>Higher value/profitability crops are sown |
| **2.** | **CROP DIVERSITY** | | | |
| *2A* | *Limited crop options ^* | *Only crops with higher direct profitability are grown* | *- Soil-borne pathogens increase*<br>*- Limited weed control & herbicide choices* | *Crop options limited to: wheat, barley, chickpeas, sorghum* |
| 2B | Diverse crop options ^ | Utilise a wider range of crops to manage the build-up and damage from soil-borne pathogens and weeds in cropping systems | - Increased soil biological activity & diversity<br>- Alternate herbicide chemistry & hence slow HR onset | Crop choice altered to ensure 50% of crops are resistant to nematodes and no more than 2 non-resistant crops in a row.<br>Two crops with same in-crop mode of action can't follow each other |
| **3.** | **NUTRIENT SUPPLY/BALANCE** | | | |
| *3A* | *Conservative nutrient supply^* | *Manage synthetic fertiliser input costs* | *- Soil fertility declining and likely crop yield penalties in good seasons* | *Crop fertiliser budget to achieve 50th percentile yield* |
| 3B | High nutrient supply ^ | Background soil fertility is boosted and crops provided with adequate nutrients to maximise yield potential. | - Soil chemical & biological fertility is maintained or increased<br>- Crops able to maximise their seasonal yield potential | Initial organic amendments and subsoil P application<br>Fertiliser budget to achieve 90th percentile yield. |
| 3C | High legume ^ | Increase inputs of biological N from legumes in system to reduce fertiliser N inputs | - Reduced N fertiliser requirements<br>- Altered weed & pathogen populations | Legumes make up 50% crops sown<br>High biomass legumes chosen in preference |
| **4.** | **SOIL QUALITY RESTORATION** | | | |
| *4A* | *No soil restoration* | *Non-grain crops are not included in crop sequences* | *- Soil quality declines and hence water capture and nutrient supply may limit system productivity* | *Grain crops only grown in crop sequences* |
| 4B | Cover crops # | Cover crops used to restore soil cover, increase organic inputs and manage weeds and diseases | - Reduced herbicide use<br>- Reduce N inputs for crops in rotation<br>- Altered weed and disease populations | Cover crops after crops leaving low ground cover<br>Brown manure (i.e. spray out) crops with yield < 50% of potential |
| 4C | Ley pasture # | Perennial ley pastures phases to rebuild soil organic matter, nutrient levels and build disease suppressive soil biology. | - Reduced herbicide use<br>- Reduce N inputs for crops in rotation<br>- Altered weed and disease populations | A phase of grass and/or legume based pastures are sown in rotation with grain crops |

**Table 2.** System modifications for experimental program at regional locations and the reference benchmark at the core site. Note the core site will also represent the Eastern Downs region farming systems.

| Trt # | System | Regional sites | | | | | |
|---|---|---|---|---|---|---|---|
| | | Emerald | Billa Billa | Mungindi | Spring Ridge | Narrabri | Trangie |
| 1 | 'Benchmark' | * | * | * | * | * | * |
| 2 | High nutrient supply | * | * | * | * | * | * |
| 3 | High legume | * | * | * | * | * | * |
| 4 | Diverse crop options | * | * | * | * | * | * |
| 7 | High crop intensity | * | * | | * | * | * |
| 14 | Low crop intensity | | * | * | * | * | * |
| 15 | Ley pasture (grass only) | | * | | | | |
| 16 | Ley pasture grass + N | | * | | | | |
| | Integrated weed mgnt | * | | | | | |
| No. of systems | | 6 | 8 | 5 | 6 | 6 | 6 |

**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.

We would like to thank those growers and advisors who have given their time to be involved in focus group meetings, who shared their perspectives and provided their input into the design of this project.

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# Chickpea Ascochyta update – what's happening in the paddock – bringing home the 2015 crop

*Kevin Moore, Leigh Jenkins, Paul Nash and Gail Chiplin*
*Department Primary Industries NSW*

**Key words**

chickpea, Ascochyta, fungicide

**GRDC codes**

DAN00143, DAN00176, UM00052

**Take home message**

- Localities where Ascochyta was found in 2014 are considered high risk for 2015 crops and growers are advised to apply a preventative fungicide before the first post-emergent rain event to all varieties including PBA HatTrick and PBA Boundary.
- From 27-30 June 2015, 49 chickpea crops in the Moree region were inspected for Ascochyta – the disease was NOT found in any crop nor in a paddock of volunteer chickpeas that were starting to pod.
- We believe the absence of detectable Ascochyta reflects judicious prophylactic management in high risk areas and lack of inoculum in low risk areas.

## What's happening in the paddock?

As of 25 June 2015, most chickpea crops in the GRDC Northern Region (NR) have had one decent rain event (lasting 2-3 days, up to 75mm); early sown crops have had two. Thus most NR chickpea crops have been potentially exposed to at least one Ascochyta infection event and early sown crops have been potentially exposed to two. In spite of these ideal conditions, Ascochyta blight, AB has not yet been detected in the limited area of the NR that has been surveyed to date. From 27-30 June 2015, 49 chickpea crops in the Moree region were inspected for Ascochyta – the disease was NOT found in any crop nor in a paddock of volunteer chickpeas that were starting to pod. A 3 July 2015 report of severe Ascochyta in crops of Kyabra east of North Star has yet to be confirmed.

## Is there a new strain of Ascochyta?

Based on a very small number of isolates of the AB pathogen, *Phoma rabiei* (previously called *Ascochyta rabiei*), there is no evidence for a new strain. GRDC work has demonstrated clearly that isolates differ in aggressiveness but not in virulence (= strains, pathotypes, races). Isolates differ in aggressiveness if some isolates cause more damage than others; they differ in virulence if some isolates can infect more varieties than others or cause differential damage on varieties. Thus whilst an isolate from Yallaroi, NSW caused more damage on all four varieties used in the experiment than did isolates from Temora NSW, the Darling Downs QKD, Murtoa VIC, Donald VIC and Melton SA, all isolates infected all varieties. A new strain would exist if the Yallaroi isolate only attacked PBA HatTrick and say Kyabra but not the other two varieties OR the Yallaroi isolate caused more damage on PBA HatTrick than it did on Kyabra.

## Where to from here?

Growers are urged to continue monitoring crops for Ascochyta 10-14 days after rain and to apply fungicides before the next rain event if warranted.

Most crops inspected to date (30 June) have had plant populations less than the minimum recommended 25 plants per sqm. If El Nino conditions develop in late winter - spring, as is predicted, these low plant populations and those conditions indicate Botrytis Grey Mould will not be a concern in 2015.

**What alternative fungicides are effective against chickpea Ascochyta?**

The large area of chickpeas planted in the NR this year and other forces have led to a shortage of registered products for chickpea Ascochyta. Pulse Australia has had discussions with suppliers and the APVMA regarding the issue of Emergency Use Permits, EUP. To date no EUP have been issued. Remember, it is illegal to use any product that is not registered or currently under permit. Should such permits be issued, the following information is provided to help agronomists and growers make informed decisions about alternative fungicides for chickpea Ascochyta.

**The 2011 GRDC pulse fungicide initiative**

Following the extreme 2010 season, GRDC and the agro chemical industry organised a series of standardised pulse fungicide trials throughout eastern Australia. The trials evaluated four products currently registered for other crops, and a coded product (MCW1086) each at three rates. These were Product X; Product Y; Product Z; and Product W. There were two control treatments (i) a low disease control based on the industry standard ie Unite 720 (chlorothalonil @ 1.0L/ha) and (ii) a high disease control where plots were not sprayed (Nil).

The Tamworth chickpea Ascochyta trial (cv Jimbour) was inoculated with Ascochyta during a rain event on 7 August 2011 and the disease progressed throughout the season, killing unsprayed (NIL) plots by mid October. Key findings from the trial were:

1. Under high Ascochyta pressure, there was no significant difference (P=0.05) in yield between 1.0L/ha Unite720 and (a) all rates of Product Y and Product Z, and (b) the two higher rates of Product X and MCW1086
2. None of the Product W rates provided satisfactory control. In a GRDC trial at Tamworth in 2010 under extreme Ascochyta pressure, 750 mL/ha Product W was outstanding having less Ascochyta than 1.0L/ha Unite720.
3. Product Y was very efficacious, even at 100mL/ha (in 2010 we only tested a single rate ie 200mL/ha and it performed very well).
4. The high efficacy of the old chemistry Product Z; indeed the Ascochyta scores for all three rates of Product Z were as good as those for the Unite control. This trial confirmed a 2003 GRDC Tamworth trial that showed 1250 g/ha Product Z provided excellent control of Ascochyta.

Whilst the 2011 trial identified which products and rates gave satisfactory control of Ascochyta in a susceptible variety, under high disease pressure, the big take home message was:

Nothing was as cost effective or more efficacious as current commercial practice ie (Unite720 @ 1.0L/ha)

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# Quality defects in chickpeas – causes, management options and research in progress

*Dr Jenny Wood, NSW Department of Primary Industries*

**Key words**

Chickpeas, tiger stripe, seed markings, seed defects, grain quality

**GRDC code**

DAN00196

**Take home message**

Seed quality defects are a risk to the good quality reputation of Australian chickpeas. We need grower and adviser help to minimise the incidence of seed markings into the future.

Pulse quality is important to provide people with food, profits to farmers, profits within the value chain, nutrition and health to consumers as well as satiety and a sensory experience. The Pulse Quality Laboratories at Tamworth are charged with the task of ensuring Australian pulses have quality attributes to meet these requirements. We do this through (1) ensuring that new pulse varieties from the Pulse Breeding Australia (PBA) Breeding Programs and National Variety Trials (NVT) are acceptable to our major markets, (2) supporting development of new food products containing pulses for Australian consumption, (3) methodology development and improvement to assess the most important qualities, (4) other research activities to improve seed quality and eliminate seed defects, and (5) post-graduate student training and supervision.

Good pulse quality creates value (= increased industry and grower income) through increasing demand for Australian pulses. Seed quality defects have the potential to reduce marketability (= reduced profits). Such defects can be visual, process-reducing (for example, reducing processing yield or quality during the manufacture of an ingredient or food), food-behavioural (causes unwanted changes in the behaviour of the ingredient or food) or sensory (undesirably affects taste or aroma).

This talk will focus on one aspect of seed quality defects – seed markings.

Seed markings are visual blemishes on the seed coat that do not affect cotyledon appearance. They have been known to occur at low levels in many desi chickpea varieties from Australia and overseas for many years. However, the incidence of one particular type of seed marking, tiger stripe/ blotching, appears to be on the increase. Evidence suggests that they are not caused by disease and we hypothesise they are triggered by environmental plant stress.

A new GRDC project commenced in 2014 to investigate the occurrence of seed markings across varieties and growing regions, and to determine the underlying causes of these defects.

Preliminary results suggest that:

- some varieties are more affected than others, hence there is a genetic component
- environment has an effect, and we are working to uncover the causative factor(s)
- sowing time can influence the presence and severity of markings, with later sowing dates generally leading to less markings in susceptible lines
- there appear to be interactions between some of these factors

Samples received from around Australia in 2014 have indicated that the percentage of seeds blemished with blotch/tiger stripe markings range from 0% up to 49% within a single sample of seed.

This project is also examining pre-harvest weather damage in chickpeas (not presented at this meeting).

Growers and advisors are requested to provide seed samples from the 2015 season again this year to help researchers identify which varieties and locations are most affected by seed defects and which are not. In addition, any samples provided will be tested for germination, emergence, seed borne diseases and moulds by Dr Kevin Moore as part of the GRDC Project DAN00176, Northern NSW Integrated Disease Management and results provided back to the sender.

The request for samples information and Sample Info Sheet will be provided at the presentation (or can be downloaded at http://www.grdc.com.au/News-ChickpeaSeedTesting).

**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.

There are many collaborators involved in this project, too many to name individually, but the organisations include NSW Department of Primary Industries, Queensland Department of Agriculture and Fisheries, University of New England, University of Western Sydney, University of Southern Queensland. The author would like to thank them for their expert contributions to this research.

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# NGA chickpea herbicide trials 2014

*Lawrence Price, Anthony Mitchell, Rachel Norton, Linda Bailey Northern Grower Alliance*

**Key words**

Chickpeas, herbicides, wild oats

**GRDC code**

NGA00003: GRDC Grower Solutions for Northern NSW and Southern Queensland

**Take home messages**

- Factor® (250g/kg butroxydim) was not effective as a knockdown for wild oats in chickpeas.
- Of the Group A herbicides, 500 mL/ha of Status® (240g/L clethodim) or mixtures of Verdict® (520g/L haloxyfop) plus Status proved the most effective brews for knockdown control of wild oats
- Clethodim (as Status) benefited from the addition of Liase® even when rain water was used as the carrier
- Screening of new herbicide registrations in chickpeas has not yet shown consistently robust options for the residual control of wild oats and key broadleaf weeds

Weed control has always been a critical part of chickpea management. This paper reports on recent trial activity for the management of a range of weeds in chickpeas; primarily wild oats (both Group A resistant and susceptible populations) but also other grass weeds and problem broadleaf weed species.

**Wild oat 'knockdown' control**

In reviews of the 2013 winter season, agronomists and farmers had raised managing resistant populations of wild oats as a major issue for the region. Wild oats are a key weed of winter crops throughout the region and for the past 30 years growers and agronomists have relied on Group A herbicides for control.

Haloxyfop a 'fop' herbicide is perhaps the most widely used herbicide in the region for knockdown of wild oats in chickpeas and other pulse crops, however resistance to this herbicide is becoming increasingly frequent. Many agronomists, where they have concerns about the Group A resistance status of wild oats in a paddock, will mix haloxyfop (e.g. Verdict 520) with a 'dim' herbicide (most commonly clethodim), other agronomists might use clethodim alone. NGA was questioned as to what was the best strategy to use.

Butroxydim (e.g. Factor) is another Group A 'dim' that although registered for wild oat control in many broadleaf crops has not been widely used in the Northern NSW/Sth Qld region. Reports have filtered up from southern Australia that in some situations butroxydim is the last group A herbicide effective against annual ryegrass. The question was asked "Could butroxydim have similar attributes against wild oats in our region?"

**What was done?**

In 2014 the NGA team conducted 4 small plot replicated trials looking at control of wild oats in chickpeas with knockdown herbicides.

Trials were situated in commercial chickpea paddocks near Mungindi, North Star, Bowenville and Edgeroi. The Mungindi and North Star sites were known to have wild oats with resistance to haloxyfop.

Aims of the trials were:

1. Does mixing haloxyfop with clethodim give an advantage in wild oat control compared to either product applied alone?
2. Can we get equal benefit by just increasing the herbicide rate?
3. Does butroxydim control fop resistant weed populations, in a similar way to clethodim?
4. Is there an advantage in adding ammonium sulphate (as Liase) to the 'dim' herbicides?

**Table 1.** Spray dates, growth stage of wild oats and water quality of trials conducted in 2014

| Site | Spray date | Wild Oat Growth stage at spraying | Water source | Bicarb ppm |
|---|---|---|---|---|
| Mungindi | July 1 2014 | 2 – 4 leaves | Goondiwindi Town water | 104 |
| North Star | June 26 2014 | 3 – 5 leaves | Goondiwindi Town water | 104 |
| Bowenville | August 11 2014 | Up to 3 tillers | Rain water | 18 |
| Edgeroi | September 4 2014 | Up to 7 tillers | Gunnedah Town water | low |

**Table 2.** Products used in trials

| Trade name | Active ingredient | Formulation | |
|---|---|---|---|
| Verdict® 520 | Haloxyfop | 520 g/L | |
| Status® | Clethodim | 240 g/L | |
| Factor® | Butroxydim | 250 g/kg | |
| Uptake® | Paraffin oil + Non-ionic surfactants | 582 g/L + 240 g/L | Adjuvant |
| Supercharge® | Paraffin oil | 471 g/L | Adjuvant |
| Liase® | Ammonium sulphate | 417 g/L | Adjuvant |

Applications were made with quadbike mounted booms. In all cases using AIXR110015 nozzles at 50 cm spacing and a water volume of 70 L/ha.

Uptake was added to all tank mixes containing Verdict or Status at a rate of 0.5%

Supercharge was added at 1% to treatments of Factor (But not when tank-mixed with Verdict)

**Results**

***Trial RN1419 Mungindi***

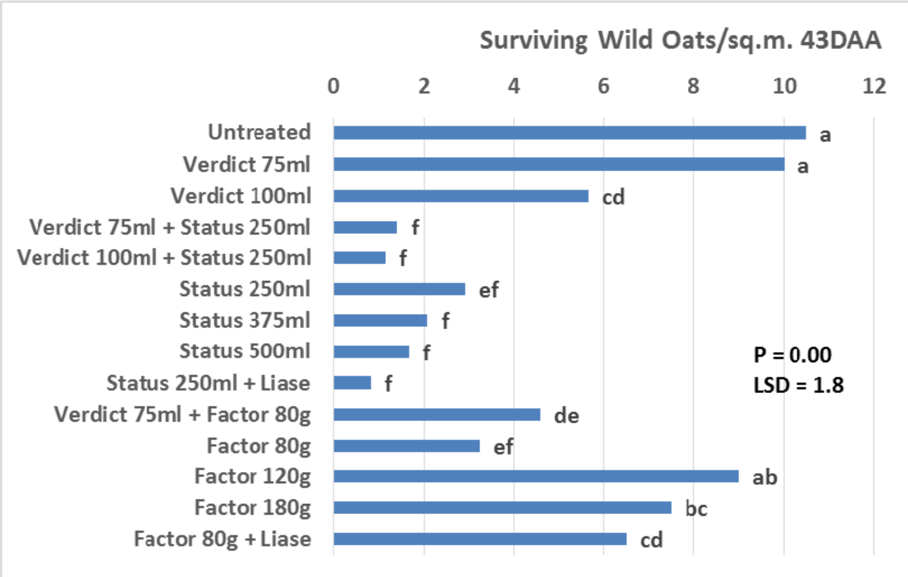


**Figure 1.** Surviving wild oats per square metre at 43 days after application at Mungindi trial

Uptake 0.5% added to all treatments containing Verdict or Status, Supercharge 1% added to all treatments ONLY containing Factor. DAA = days after application

**Summary**

- Verdict applied alone failed to give effective control
- Addition of 250 ml/ha of Status to the 75mL/ha rate of Verdict improved efficacy compared to Verdict applied alone at the same rate
- Factor applied alone or as a tank-mix with Verdict failed to give effective control
- Status was the most effective herbicide
- There was a non-significant rate response for Status.
- Addition of Liase trended to improve the performance of Status, but not Factor, in low bicarb water

*Trial RN1420 North Star*

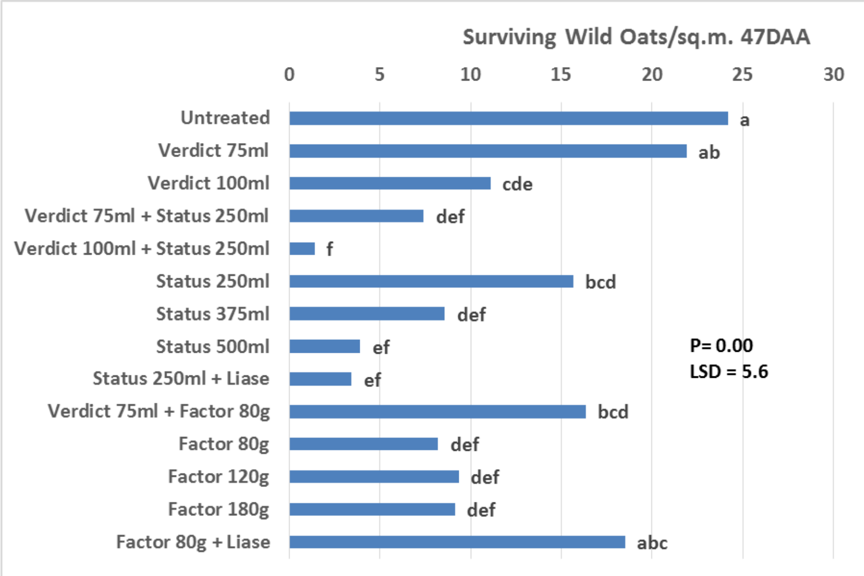


**Figure 2.** Surviving wild oats per square metre at 47 days after application at North Star trial

Uptake 0.5% added to all treatments containing Verdict or Status, Supercharge 1% added to all treatments ONLY containing Factor. DAA = days after application

**Summary**

- Similar pattern of results to the Mungindi site
- Verdict applied alone failed to give effective control
- Factor applied alone or as a tank-mix with Verdict failed to give effective control
- The Verdict + Status tank-mix gave the best level of control
- There was a significant rate response for Status.
- Addition of Liase significantly improved the performance of Status but not Factor

*Trial LB1409 Bowenville*

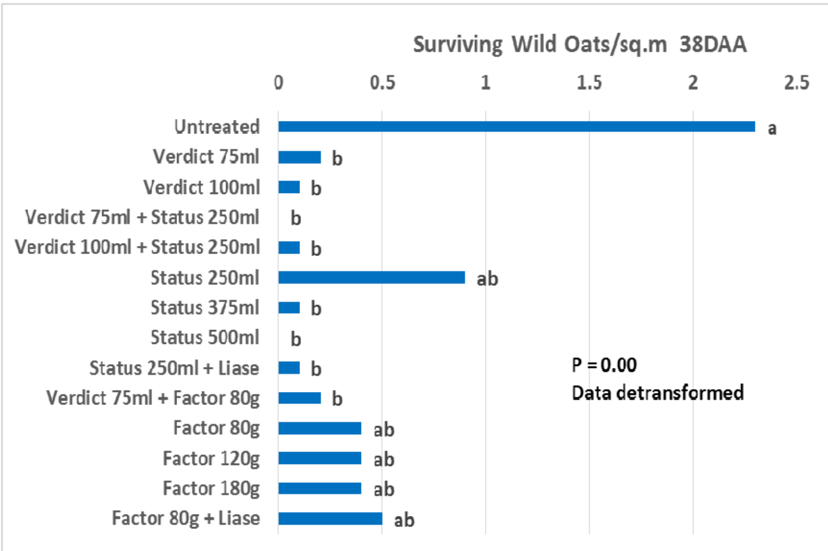


**Figure 3.** Surviving wild oats per square metre at 38 days after application at Bowenville trial

Uptake 0.5% added to all treatments containing Verdict or Status, Supercharge 1% added to all treatments ONLY containing Factor.    DAA = days after application

**Summary**

- Verdict gave effective (although not complete) control of wild oats at this site
- Factor applied alone was not considered commercially acceptable giving ~ 80% reduction in surviving plant numbers. Factor gave no improvement when tank-mixed with Verdict compared to Verdict applied alone
- The Verdict + Status tank-mixes gave very good control, with complete control achieved by the nix of 75ml/ha of Verdict and 250 ml/ha of Status
- There was a non-significant rate response for Status.
- Addition of Liase trended to improve the performance of Status, but not Factor – even though rain water was the carrier

***Trial AM1409 Edgeroi***

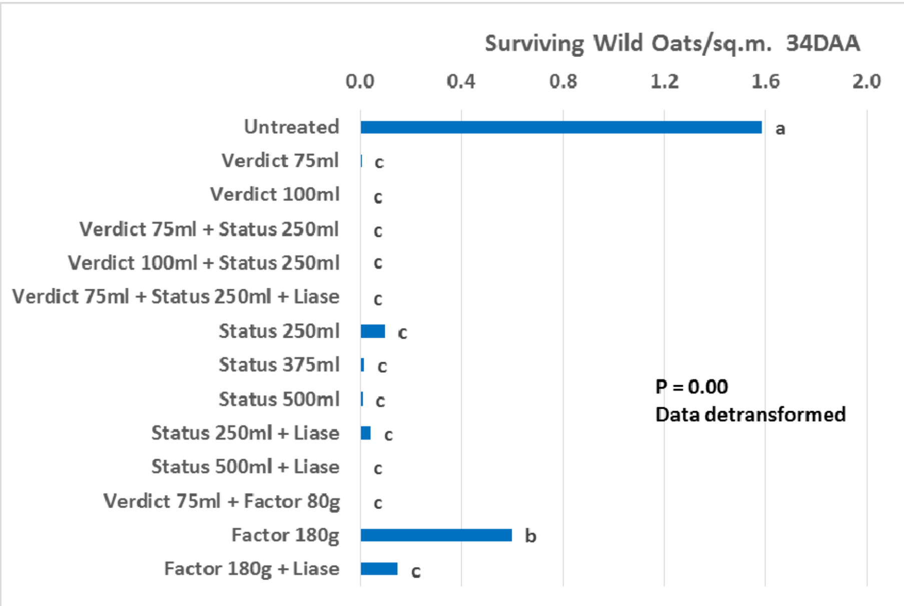


**Figure 4.** Surviving wild oats per square metre at 34 days after application at Edgeroi trial

Uptake 0.5% added to all treatments containing Verdict or Status, Supercharge 1% added to all treatments ONLY containing Factor.    DAA = days after application

**Summary**

- Treatment list was changed at this site following earlier results
- Verdict either alone or in mixture gave excellent control of wild oats at this site
- Factor applied alone at 180 g/ha only provided an unacceptable 60 % reduction in wild oat number
- As in the other trials there was a rate response for Status however this was not statistically significant. The addition of Liase trended to improve the performance of Status

**Conclusions wild oat knockdown control**

Remarkably similar responses considering the different resistance profiles of the wild oat populations.

- Verdict (alone) provided good control of the Bowenville and Edgeroi populations, despite these being substantially larger weeds, thus indicating 'fop' susceptible populations
- Factor applied alone was not effective at any of the sites.
- Addition of 250 mL/ha of Status to Verdict improved efficacy where the haloxyfop resistance was in question
- Addition of Factor to Verdict did not improve efficacy to acceptable levels
- A numerical rate response for the herbicide Status was indicated in all trials, although mostly this was not significant
- There was a Liase response when added to Status, but not to Factor, irrespective of the water quality

**Grass 'residual' control**

NGA established seven trials in winter 2014 to evaluate the potential of new chemistry on residual management of key grass weed species. Weed data was generated at four sites with efficacy against wild oats, windmill grass and liverseed grass (germinating in the spring).

Although most of the herbicides provided some level of suppression of wild oats, none provided a commercial level of control, with TriflurX® (480g/L trifluralin) at 1.7 L/ha providing the highest level of control. Two of the four sites however had a level of cultivation in recent seasons and this may have impacted on the level of control by having weed seeds spread through the soil profile with seeds at depth not being well controlled from an incorporated by sowing (IBS) application.

At a site near Condamine sprayed in mid May 2014, useful data was obtained on liverseed grass management. The liverseed grass emerged in late August/early September nearly 4 months after herbicides were applied as an IBS application at planting. The most effective herbicides were from the dinitroanilines class (pendimethalin (e.g. Stomp®) or trifluralin (e.g. TriflurX).

An additional series of 9 trials targeting activity on wild oats, awnless banyard grass and feathertop Rhodes grass are underway in 2015.

**Broadleaf 'residual' control**

Two trials were established in 2014 to evaluate the potential of new chemistry on residual management of key problem broadleaf weeds. Data was generated on Mexican poppy, climbing buckwheat as well as common sowthistle. Useful suppression was achieved from a number of newly registered chickpea herbicides and additional trials are underway in 2015.

**Acknowledgements**

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

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