GRDC Grains Research Update

Grains Research UPDATE

WALGETT

Thursday, 25th February 2016

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Grains Research UPDATE

Walgett GRDC Grains Research Update

Thursday 25th February 2016, Walgett District Sporting Club

Agenda

Time	Topic	Speaker (s)
9:00 AM	Welcome	GRDC
9:10 AM	Farming systems for drought prone environments.	Simon Fritsch (AgriPath)
9:40 AM	Soil water and drivers of fallow efficiency.	Brett Cocks and Tony Webster (CSIRO)
10:15 AM	Accurate and efficient measurement of soil water in dryland systems – grower experience replacing probes with EM38.	Byron Birch (Rimanui Farms)
10:35 AM	Fallow efficiency - what happens if stubble is concentrated in rows?	Greg Rummery (Greg Rummery Consulting)
10:55 AM	Morning tea	
11:25 AM	Wheat row spacing, population and time of sowing research. Implications for future planting rig purchases and row spacings in western regions.	Mick Brosnan (B&W Rural / Mungindi Cropping Group)
11:50 AM	Pushing pulse crop yield in north western NSW.	Andrew Verrell (NSW DPI)
12:15 PM	Lunch	
1:15 PM	What is the role and fit for dual-purpose crops in low rainfall western grain growing regions? Mitigating seasonal risk and optimising profit.	Lindsay Bell (CSIRO)
1:45 PM	Drought proofing management - rotations & farming methods to survive in a dry and variable climate.	Panel session: Greg Rummery, Lindsay Bell, Simon Fritsch & Ken Stump
2:25 PM	Sowthistle glyphosate resistance survey findings. Overview of herbicide resistance testing options and costs.	Annie Van der Meulen (DAF Qld)
2:50 PM	Long fallow disorder and VAM deficiency - implications for P and Zn nutrition in 2016 winter crops (Via Videolink)	Nikki Seymour (DAFQLD)
3:10 PM	Close.	

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Better profits from good soil water decisions

Dr Peter Wylie and Simon Fritsch, AgriPath

Key words

Soil water, Water Use Efficiency, Yield gap, Rotations, Opportunity Cropping

Take home message

Profit on the average farm can be doubled by good planning of farming systems, operations, crop choice and attention to detail on crop agronomy. Crop margins can be improved by optimising soil water storage and making decisions based on soil moisture, seasonal outlook and time of planting.

Water Use Efficiency benchmarks can be used to estimate attainable yield for various amounts of soil water or the total water available, if looking back in hindsight. WUE has a wide variation and the accuracy of estimating attainable yield is improved if benchmarks are used for low, medium and high yields. For wheat and sorghum these WUE benchmarks in the Northern Region are 9, 12 and 15 kg/ha/mm for low, medium and high yields respectively.

Introduction

Average farm profit on grain farms in New South Wales, according to ABARE surveys, is around 2-3% Return on Assets Managed (ROAM). From here there a large gap, to move up to the profits achieved by the Top 20% of benchmarked farmers, of 8 to 10% ROAM. Top performing farms produce an additional $500,000 profit each year compared to their peers.

Part of this profit gap is the difference between average farm yields and the attainable yields which result from good farming practices. Across the Northern Grain Region this yield gap is some 50 to 90%. Farm profitability would more than double with a 50% increase in yield.

Closing the yield gap requires getting a lot of things right, which requires time to be spent on management, seeking advice and planning for good crop margins and farming operations.

Good yields are about more than weeds and fertilisers. Farming systems are the key to good profits. Well-planned rotations which manage disease, nematodes and weeds can provide extra gains in crop yields, by improving timeliness and reducing grain losses from weather risks.

Yields are a product of soil water, in-crop rainfall and water use efficiency. Good farm profits depend upon making good decisions based on soil water and profit margins which might be achieved from various planting opportunities.

1. What is an extra 20mm of soil water worth

Good practices for storing rainfall during fallow may result in an extra 20mm of soil water, which on the average can result in an extra 400 kg/ha of wheat and around 50% more profit. Extra soil water, not only produces more grain, it improves the water use efficiency on the total amount of water used by the crop.

The results of wheat yields at Gunnedah, modelled using APSIM, show an extra 24mm of soil water increased WUE from 11 to 12 kg/ha/mm and yield by 537 kg/ha. At Coonamble an extra 16 mm increased yield by 381kg/ha.

Table 1. Effect of soil water capacity on water storage and crop yield
APSIM modelling by G. Mclean, DAFF Qld. 2014

Soil PAWC mm	Wheat May 30 Plant	Planting soil water	In-crop Jun - mid-Oct	Harvest soil water	WUE kg/ha/mm	Yield average kg/ha
150	Gunnedah	136	236	28	11.1	3814
180	Gunnedah	158	236	30	12.0	4351
	Increase	22			24.1	537
150	Coonamble	126	201	16	8.7	2716
180	Coonamble	142	201	17	9.5	3097
	Increase	16			23.4	381

Profit would increase from $280/ha to $408/ha with an extra 20mm at Gunnedah, a rise of 46% and for a yield increase of 0.47 t/ha from an extra 20mm at Coonamble, profit would rise 75% from $123 to $216/ha.

2. Optimising soil moisture

Building a healthy soil is the key to good infiltration of rainfall. In most seasons there is some heavy rainfall which causes runoff during a summer fallow. Soil cover is maximised by zero-tillage and a well-planned rotation. With minimal compaction as a result of controlled traffic the soil will have an improved infiltration rate. With high levels of organic matter input, soil structure and earthworm numbers improve over the years, rather than decline.

At Gunnedah, rainfall during a summer fallow is 400 mm on average, of which around 25%, or 100 mm is commonly stored for the next crop. Good fallow management may increase storage of fallow rainfall to around 30% and result in average soil water storage of 120 mm.

Good control of weeds during fallow is important for good water storage. Delayed weed control or a few escapes can quickly reduce the water stored by 20 mm or more. A good rotation program is important for managing weeds and herbicide resistance.

Residual herbicides can keep down weed control costs and help in managing glyphosate resistance grass weeds. Residual herbicides can also improve timeliness by taking the pressure off the fallow spraying, when weed control in hot weather is needed in a short space of time. Residual herbicides require planning and sometimes locking in a crop sequence, to avoid problems with plant back periods and effects on the following crops.

Good spray techniques are important for good weed control and soil water storage. Farmers should seek advice on nozzle selection, water rates, adjuvants, speed of spraying and weather.

3. Attainable Yield projections based on WUE

Rather than use a fixed estimate of attainable wheat or sorghum yields for a district, it is more useful to calculate attainable yield using water use efficiency (WUE) benchmarks for a particular soil type or the amount of soil water available.

WUE calculations in summer rainfall areas need to take into account soil moisture at planting and harvest. Evaporation is variable in the Northern Grains region. It should be ignored, because it shows high WUE in a dry season when in fact it can be quite low. WUE is calculated by dividing grain yield by water available, which is soil water at planting, plus in-crop rainfall less an estimate of soil water at harvest.

Data from 200 farm and trial observations on wheat in the Northern Region over the 7 years 2005 to 2013, has shown an average yield of 3.36 t/ha with a WUE of 12.3 kg/ha/mm.

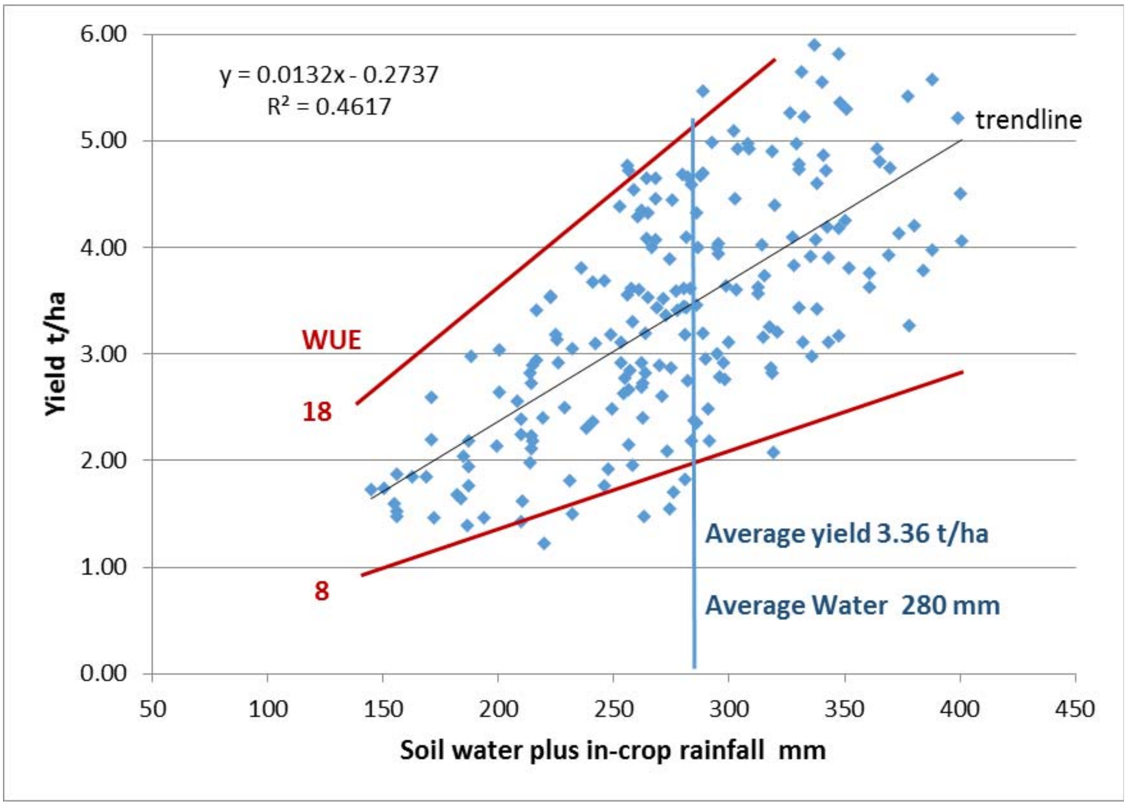

Figure 1. Yield of wheat vs water available in the Northern Grains Region
(Trial data and farm records 2005-2013, collated by Agripath)

WUE is mostly within the range of 8 -18 kg/ha/mm, with the major variation being an increase in WUE as the yield increases. One explanation for WUE improving is the increase in Harvest Index, which is the ratio of grain to total above ground biomass. At low yields the harvest index is low due to fewer heads per plant, each with less grains and lower grain weight. The harvest index of wheat is 0.2 at a yield of 2 t/ha and peaks at 0.4 when yields are above 4 t/ha. (See Figure 2)

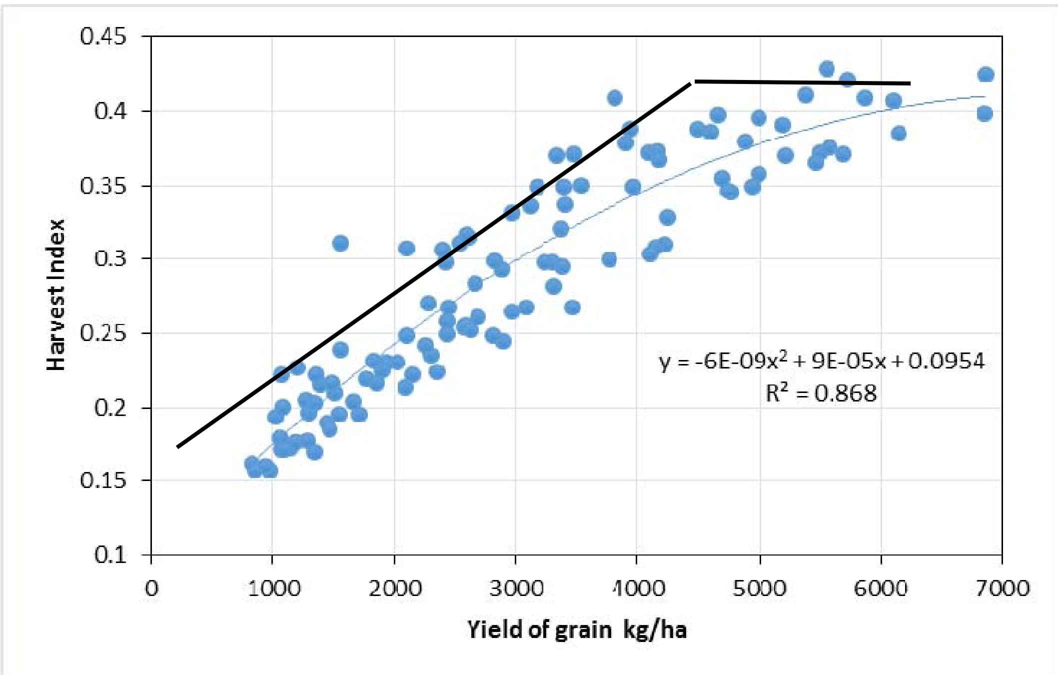

Figure 2. Harvest Index of wheat at Gunnedah (100 years of Apsim simulated yields)

Table 2. WUE data and benchmarks at low, medium and high yield levels
Data is from trials and farm records, across the Northern Grains Region: 2007-2013

	Low yield	**Medium**	**High yield**
Wheat Yield Range	**<2.5 t/ha**	**2.5-4 t/ha**	**>4 t/ha**
Observed WUE	9.01	11.86	15.07
STDEV	1.87	1.92	2.04
Benchmark for WUE	9	12	15
Sorghum Yield Range	**<3 t/ha**	**3-5 t/ha**	**>5 t/ha**
Observed WUE	8.6	11.4	15.2
STDEV	1.48	2.13	2.60
Benchmark for WUE	9	12	15
Chickpea Yield Range	**<1.5 t/ha**	**1.5-2.5 t/ha**	**>2.5 t/ha**
Observed WUE	6.55	8.55	10.46
STDEV	1.02	1.61	1.81
Benchmark for WUE	7	9	11

The wide range in WUE values means that using the average of 12 kg/ha/mm is a crude benchmark. Using more than one number for WUE will improve the accuracy and usefulness of this benchmark, both in predicting yield and reviewing yield in hindsight. Data in Table 2, shows the average WUE for wheat in the Northern Region at low, medium and high yields.

These values for WUE are in accordance with the French and Schultz benchmark of 55 kg/ha of wheat biomass per mm of water transpired. When soil evaporation is included in the equation, 37 kg/ha of biomass is produced per mm of water (French and Schultz 1984). At a low yield level, with a harvest index of 0.2, there would be 7.4 kg/ha of grain per mm, rising to 14.8 kg/ha of grain, with a harvest index of 0.4 at high yields.

Attainable yields in the table below are derived from average rainfall and the WUE benchmarks derived from a mix of trial and farm data. They compare well with APSIM modelled yields which show variation in potential yield for soils of different plant available water capacities (150 to 200 mm).

Average rainfall during summer, between November and May at Gunnedah is close to 400mm, with the potential to store 110 mm of soil water. An extra 28 mm of soil water at the start of the fallow brings this to 138 mm on average at wheat planting. With average winter rainfall from June to September of 198 mm this means 308 mm of water is available to a wheat crop, which at 12.5 kg/ha/mm is an attainable yield of 3.84 t/ha.

Table 3. Attainable yield estimates of wheat and sorghum in Northern NSW

	Planting soil water	In-crop Jun - mid-Oct	Soil water at harvest[1]	Available water (mm)	WUE kg/ha/mm[2]	Yield average[3]	APSIM yield 150mm[4]	APSIM yield 180mm[5]
Attainable wheat yield (t/ha) – Northern NSW - May 30 plant								
Goondiwindi	141	176	25	292	11.5	3.35	3.4	3.92
Gunnedah	138	198	28	308	12.5	3.84	3.81	4.35
Moree	130	173	23	280	12	3.36	2.98	3.47
Coonamble	106	159	16	249	12	2.98	2.72	3.10
Walgett	106	142	20	228	11	2.51	2.53	2.90
Attainable Sorghum Yield – September 30 plant								
Goondiwindi	149	203	28	324	12	3.89	3.61	4.34
Gunnedah	136	274	14	396	13	5.15	3.65	4.29
Moree	121	252	22	351	11	3.85	3.08	3.72
Coonamble	118	137	15	240	11	2.64	2.28	2.54
Walgett	111	148	14	245	11	2.70	2.3	2.59

1. Soil water at harvest time estimated by APSIM – average over 100 years
2. WUE benchmarks from trial and farm data collated by Agripath
3. Yield calculated from average rainfall (Rainman) and WUE
4. APSIM simulated yield over 100 years, for a soil with 150mm PAWC
5. APSIM yield with 180mm PAWC soil, 200mm at Gunnedah

4. Making decisions on double crops

Decisions on which crops to grow and the rotation program are important for good farm profit. Changes to fallow length and planting opportunity crops should be based on potential crop margins, which are influenced by soil water and commodity prices.

Too much opportunity cropping can result in a string of low margin crops and low farm profitability. Including some long fallow in cropping plans can reduce risk and boost profit in dry years. In the example below, for the Liverpool Plains, the combined margin of a double crop of mung bean and the following crop of sorghum is less than a sorghum crop on long fallow. This may not always be so and depends upon the price.

The key is to evaluate the potential margin of the crop based on soil moisture and to decide whether it is good enough to proceed.

Table 4. Margins from crops with different fallow length and price

	Mung Bean double crop Average $/t	Sorghum after mung bean	Sorghum on long fallow	Mung Bean double crop High $/t
Yield (t/ha)	1	3.5	6	1
Price	680	240	240	1200
Gross $/ha	680	840	1440	1200
Fertiliser:	30	118	178	30
Seed	40	35	35	40
Fallow sprays	40	40	60	40
Weeds, Pests	75	45	45	75
Fuel & Repairs	90	90	105	90
Harvest costs	50	50	55	50
Freight & Misc.	45	92	145	45
Labour and machinery	160	190	215	160
Total costs	530	660	838	530
Gross Margin	150	180	602	670

There are advantages of long fallows, where soil water storage allows, such as reducing the pressure of harvest and allowing more use of residual herbicides – which may in turn help manage herbicide resistance and keep down the cost of fallow weedicides.

Decisions on fallows and other aspects of crop sequencing should be made to favour the most profitable or pillar crop. If sorghum is the pillar crop, then it might be appropriate to grow some or all of it on a long fallow from wheat or barley. If chickpea is the most profitable crop, then it is not given the best opportunity for yield if it is all grown as a double crop after sorghum. If there is not a reasonable amount of soil water to grow as a double crop after sorghum, some chickpea may be grown on a fallow. In western districts, sorghum might well be late planted and harvested in May or June. A fallow over the next summer may store good soil moisture for a high margin chickpea crop.

5. WUE declines with soil water and planting time

One of the most important determinants of wheat yield is the decline in yield which occurs with delays in planting. The WUE of wheat declines around 0.5 kg/ha/mm for each week of delay past the optimum time around mid-May, increasing to 0.8kg/ha/mm after mid-June. Yield loss from late planting is worst in dry years with a hot finish. If WUE is 12 kg/ha/mm for wheat at Gunnedah, planted in mid-May, it will decline to around 8 kg/mm for wheat planted in early July.

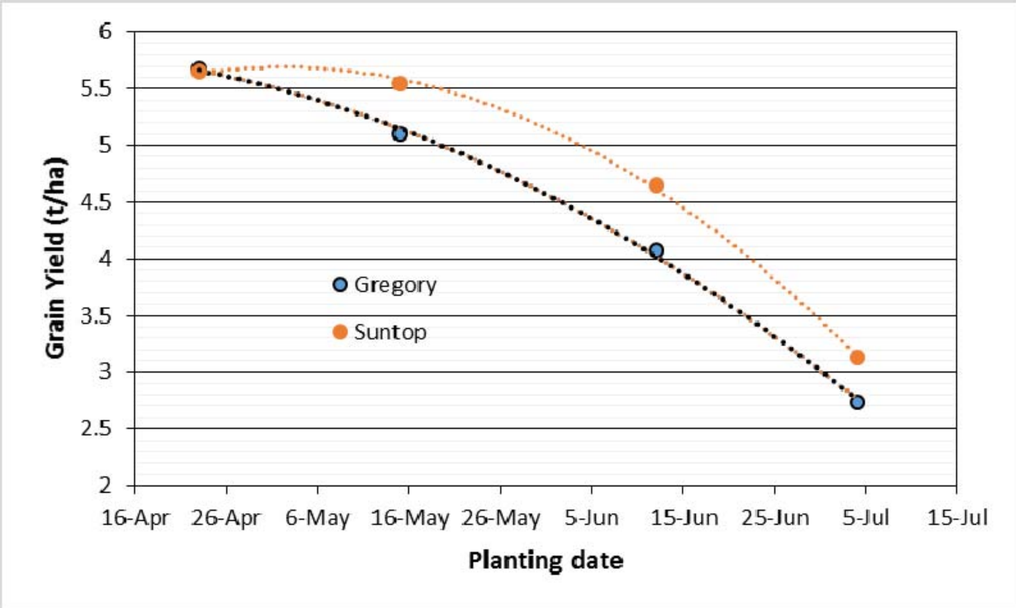

Figure 3. Yield of wheat at four sowing times, Narrabri 2014 (Graham et al 2015)

The loss in yield makes a huge difference to profit potential, with estimates of profit from wheat at the optimum time of more than four times that of wheat planted six weeks late.

Table 5. Effect of planting time on WUE, yield and profit of wheat.
Data from Agripath benchmarking

	Liverpool Plains Good soil water: 150 mm		**Liverpool Plains Low soil water: 90 mm**	
Wheat planted:	mid May	Late June	mid May	late June
Average water (mm)	308	305	248	245
Water use efficiency	13	9	11	7.7
Yield (t/ha)	4.00	2.74	2.72	1.89
Price	250	250	250	250
Gross $/ha	1000	685	680	471
Fertiliser	144	104	100	80
Seed	30	30	30	30
Weeds, Pests	75	75	75	75
Fuel & Repairs	90	90	90	90
Harvest costs	50	50	50	45
Freight & Miscell.	92	75	74	62
Labour & Machinery	181	181	181	181
Total costs	660	605	600	563
Gross Margin	340	80	80	-92

This loss from late planting is much greater than the risk of loss from frost. Even late plantings can be damaged by frost, while it is not much of a proposition to grow wheat with a profit potential which may be less than $50/ha. See Table 5. This effect of planting time on profit highlights the benefits of moisture seeking on wheat margins, if more wheat crops can be planted at the optimum time.

6. Using yield estimates to vary management decisions

Yield estimates using soil water and WUE benchmarks can be useful for making better decisions on fertiliser and other aspects of crop agronomy, such as varietal selection or seeding rate.

An example is that sorghum yield potential in the higher rainfall areas is likely to exceed 10t/ha in 30% of years, but yields in these years are likely to be limited by nitrogen supply. Adjusting N application at planting can be profitable using yield estimates at planting, based on soil moisture and seasonal outlook. Improved soil moisture and seasonal outlook (Table 6) show rising yield estimates. The SOI is more useful for summer crop than winter crop and rainfall for much of the Northern Grains Region is greater on average with a positive SOI, rather than a negative one.

A second way to improve nitrogen supplies to improve sorghum yields in above average rainfall years is to regularly apply feedlot manure or recycled organics. An application of 10 t/ha of feedlot manure will contain around 160 kg N, mostly in an organic form. In a dry summer there will be very little nitrogen released from the manure, but in a wet season when conditions are favourable, 30 to 50 kg of N may be mineralised. If an additional 40 kg N becomes available in a wet season, it could be enough to improve sorghum yields by 2.5 t/ha, assuming grain protein in a high yielding year is likely to be around 8%.

Table 6. Nitrogen required by sorghum according to soil moisture and SOI – Gunnedah

Soil water mm	In-crop rainfall SOI <-5*	Average expected rainfall	In-crop rainfall SOI >+5*	Expected WUE kg/ha/mm	Yield estimate t/ha	Nitrogen required kg/ha**
80	175			10	2.55	43
80		205		11	3.13	53
80			220	12	3.60	61
160	175			14	4.69	80
160		205		15	5.47	93
160			220	16	6.08	103

*SOI is for August and September prior to a Sept 30 sowing, with data from Rainman.

** Nitrogen in grain at 9.5% protein – depending upon soil N, more may needed to grow the crop

A third way to improve the supply of N for a good year is simply to increase the annual N fertiliser rate. If the rate was increased to 22kg N/t., rather than a 17kg/t target, this would result in an extra 30 kg N being applied for a yield estimate of 6 t/ha. The extra N could increase yield by around 1.5 t/ha in a good year. If 4.5 tonnes of extra sorghum was produced in the highest yielding 3 years over a 10 year period, this could be worth $1000 for an outlay of $420/ha. In the drier seasons, some of the extra N would be exported from the farm as higher protein levels in the grain, but overall the extra N might contribute to a small increase in N reserves in soil organic matter.

7. Rotations and resilient farming systems

Good farming systems involve crop selection, rotations, sound practices for zero-tillage and planting, combined with good risk management. Well-planned rotations which manage disease, nematodes and weeds not only improve crop yields, they can improve timeliness, keep down costs and reduce grain losses from weather risks.

It is not possible to make good profits without managing problems such as nematodes and crown rot. In combination these two problems could be dragging down wheat yields by 20% and profit by 40%. Nematodes require a plan to keep soil populations low, using break crops, such as sorghum and canola. New varieties of wheat, such as Suntop⚬, offer potential to suppress nematode populations.

Management of weeds, particularly glyphosate resistant summer grass weeds, is another factor driving decisions on rotations. Rotation plans which include some fixed cropping plans and long fallows can pave the way for increased use of residual herbicides to help reduce costs and to better manage glyphosate resistance.

Timeliness of operations, a poor strike or harvest losses can affect yield and drag down profit. A rotation program which provides diversification of crops can make a big difference to the timeliness of planting and harvesting. For example, a program with barley, wheat and chickpea has a planting and harvest window spread over two or three weeks, rather than one week for wheat alone.

8. Monitoring moisture and analysing data on yield, WUE and profit

In most years, somewhere on the farm, a high yielding area of crop shows what is possible. Yield maps, EM surveys, soil moisture and fertility testing and trials measured by yield maps can help to understand yield differences and the limitations of soils on a farm.

Moisture is the key to grain yields and measuring soil water holding capacity and soil water at planting time can improve decision making. EM measurements allows rapid assessment of soil moisture and soil moisture variability across paddocks.

Benchmarking of crop yields and WUE can indicate where there may have been problems with such things as fallow moisture storage, timeliness or not enough fertiliser.

Acknowledgements

The research undertaken as part of this project is made possible by the growers and the support of the GRDC, the author would like to thank them for their continued support. Some of the information comes from a GDRC project: **The economics of closing the Yield Gap in the Northern Grains Region.**

References

French R. and Schultz J. 1984. Water use efficiency of wheat in a Mediterranean-type environment. 1 The relation between yield, water use and climate. Aust. J. Agric. Res. 35(6) 743-764

Graham R. 2015. Wheat variety response to sowing time. GRDC Grains Research update Goondiwindi.

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

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CSIRO Agriculture Canberra[1] and Toowoomba[2]

Key words

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

GRDC code

CSP00170 and past projects CSA00013 and ERM00002

Take home message

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

Plant available water at sowing and fallow efficiency

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

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

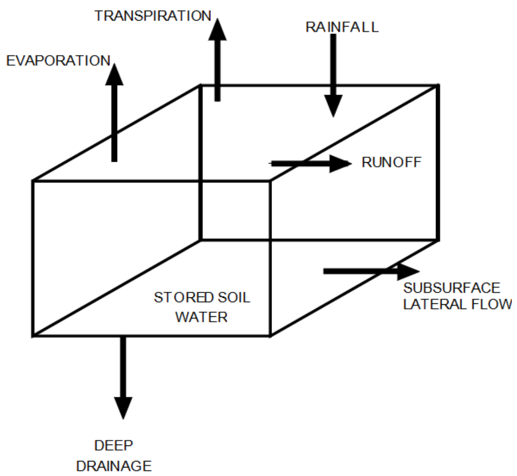

Figure 1. The relative magnitude of the different water balance terms determines the balance of inputs and losses and hence the fallow efficiency.

Impact of soil properties on evaporation

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

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

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

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

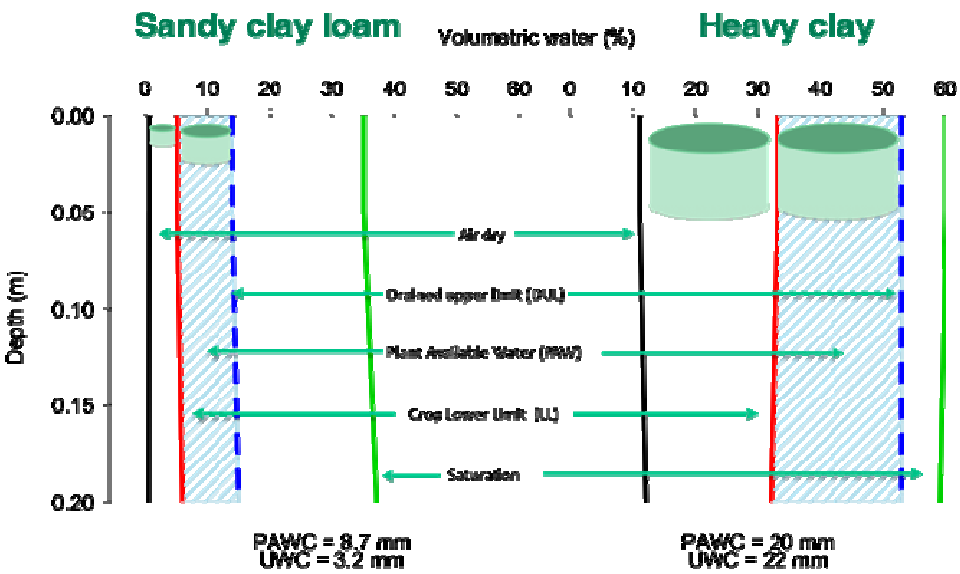

Figure 2. Conceptual diagram of the difference in unavailable water bucket size (UWC) in the surface 20 cm of a sandy clay loam and a heavy clay soil

Impact of rainfall pattern

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

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

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

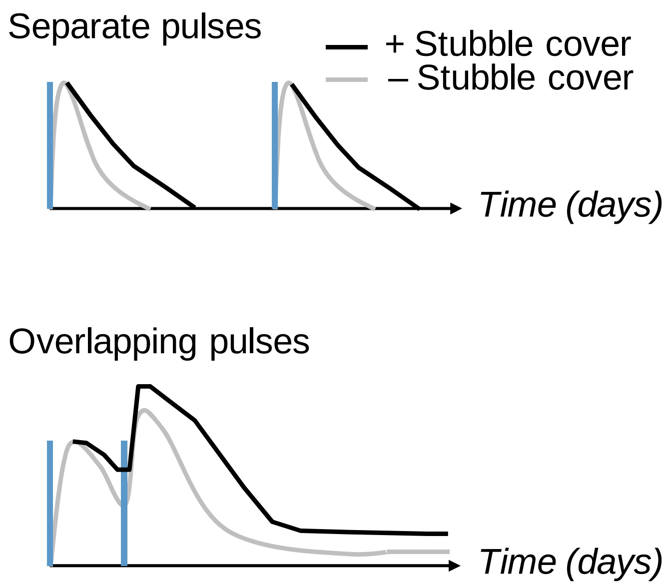

Figure 3. Rainfall events (vertical blue bars) cause pulses of soil water that last for different amounts of time in the presence (black lines) or absence (grey lines) of stubble. When pulses overlap, more water infiltrates beyond the evaporation zone in the presence of stubble cover and this will increase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

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

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

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

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

Final remarks

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

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

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support. The concepts and findings presented in this paper were developed as part of GRDC projects CSP00170, CSP00111, CSA00013 and ERM00002.

References

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

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

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

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

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

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

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

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

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

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Methods and tools to characterise soils for plant available water capacity

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Key words

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

GRDC code

CSP00170

Take home message

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

Plant available water and crop management decisions

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

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

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

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

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

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

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

Plant Available Water Capacity (PAWC)

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

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

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

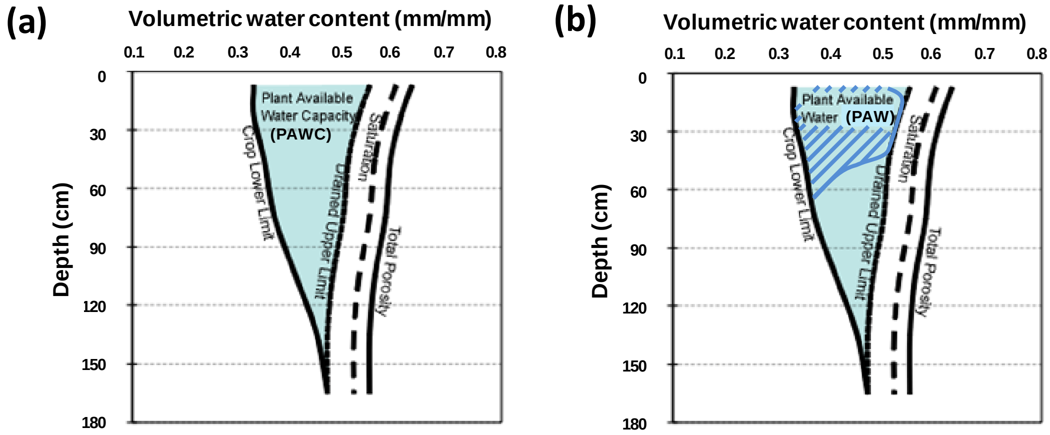


Figure 1. (a) The Plant Available Water Capacity (PAWC) is the total amount of water that each soil type can store and release to different crops and is defined by its Drained Upper Limit (DUL) and its crop specific crop lower limit (CLL); (b) Plant Available Water (PAW) represents the volume of water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

Plant Available Water (PAW)

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

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

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

Field Measurement of PAWC

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

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

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

Pitfalls and common mischaracterization issues

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

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

DUL

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

CLL

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

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

General

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

Where to find existing information on PAWC

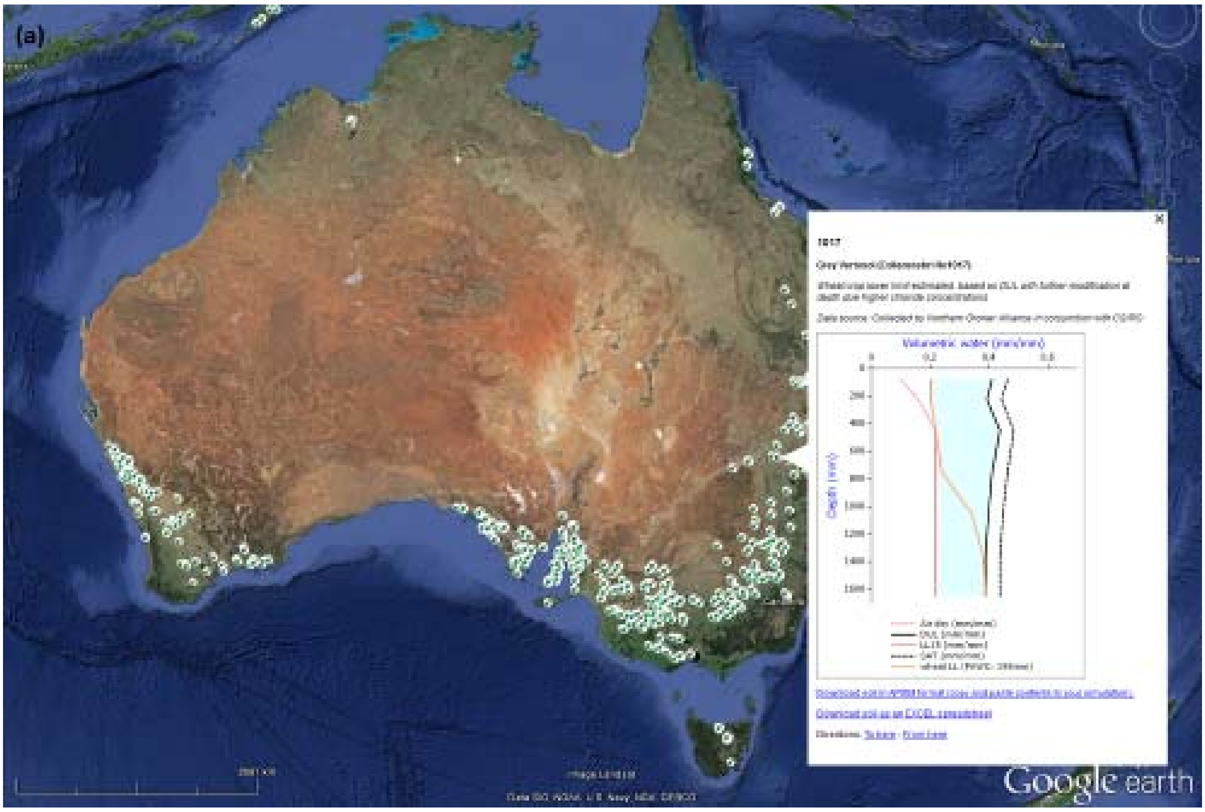
Characterisations of PAWC for more than 1000 soils across Australia have been collated in the APSoil database and are freely available to farmers, advisors and researchers. The database software and data can be downloaded from https://www.apsim.info/Products/APSoil.aspx. The characterisations can also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

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

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

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

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



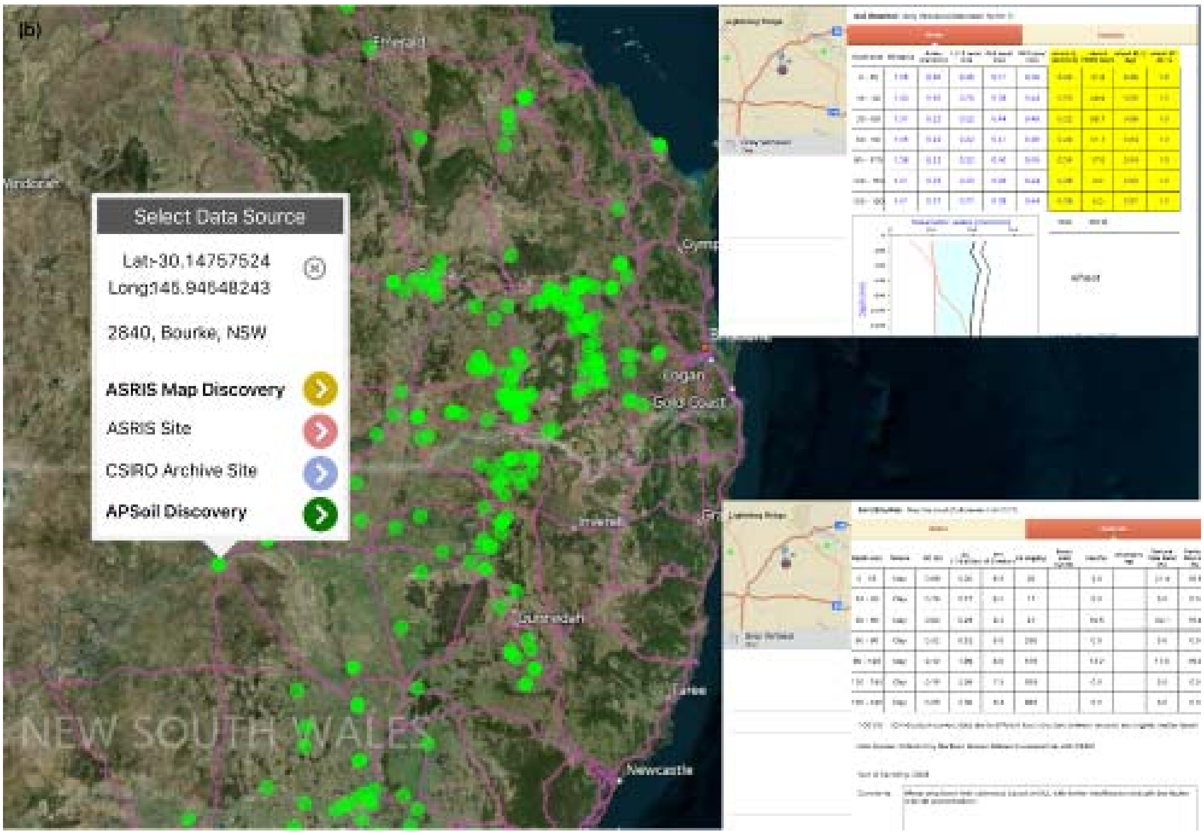


Figure 3. Access to geo-referenced soil PAWC characterisations of the APSoil database via (top) Google Earth and (bottom) SoilMapp (APSoil discovery screens as inserts)

Factors that influence PAWC

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

The effect of texture on PAWC can be seen by comparing some of the APSoil characterisations from the northern region, as illustrated below (Figures 4-6). The soil's structure and its chemistry and mineralogy affect PAWC as well. For example, subsoil sodicity may impede internal drainage and subsoil constraints such as salinity, sodicity, toxicity from aluminium or boron and extremely high density subsoil may limit root exploration, sometimes reducing the PAWC bucket significantly.

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

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

Walgett – Collarenebri - Pilliga

The *Profile Descriptions - District guidelines for managing soils in north-west NSW* report (Daniells et al. 2002) provides descriptions of the soils in the Walgett, Pilliga, Moree, Coonamble and Coonabarabran areas, including PAWC data for select soils. This is a valuable resource that complements the existing APSoil characterisations and used the same methodology for the PAWC characterisations.

The report describes characterised soils in the Walgett area as being dominated by Grey and Brown Vertosols, which are all strongly sodic (and dispersive) below 15 or 60 cm and alkaline. Most are also saline in the deeper subsoil. PAWC for wheat is usually high and frequently in the 200-220 mm range, but some of the APSoil characterisations confirm that smaller and bigger buckets do occur depending on texture and subsoil constraints in particular (see e.g. Figure 4).

Soils included in the Profile Descriptions report for the area between Collarenebri, Mungindi and and Moree are described as black and grey vertosols which have lower PAWC than the 'true black earths' east of Moree (PAWC 160-205 mm). The soils are strongly sodic (and dispersive) below 30 or 45 cm, which explains their reduced PAWC. Crops respond differently to subsoil constraints, resulting in different PAWC (Figure 5). Where the differences are small, they could also be due to measurement error (including due to seasonal variation).

We have included two lighter textured soils from the Profile Descriptions report from the Pilliga area to illustrate the effect that their lighter texture has on PAWC (Figure 6b,c).

(As there are only limited APSoil characterisations in this area, soil information and profile descriptions draw on the Profile descriptions report and the work in characterising these soils by the authors Ian Daniells, Bill Manning and Luke Pearce.)

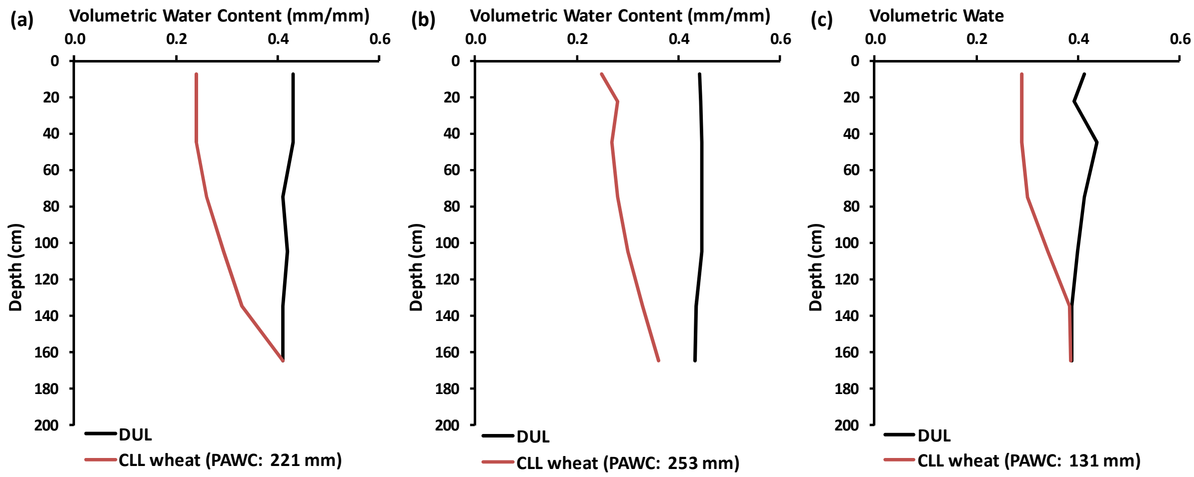


Figure 4. Select soils west of Walgett (see (a), (b) and (c) below):

(a) Grey Vertosol (APSoil 1013) (also W79 in Profile Descriptions report). Strongly sodic subsoil below 90 cm. Rotten Plain land system unit (low-lying back plains of Quaternary alluvium, periodically partially inundated by local run-off or floodwaters; depressed to 4m; land systems unit report via ESpade).

(b) Grey Vertosol (APSoil 1015) near Angledool Lake with a deeper and hence larger PAWC profile not limited by subsoil constraints.

(c) Grey Vertosol (APSoil 1016) between Walgett and Cumborah in alluvial deposits. Particle size and chemistry data not available, but shape suggests subsoil constraints limit the PAWC.

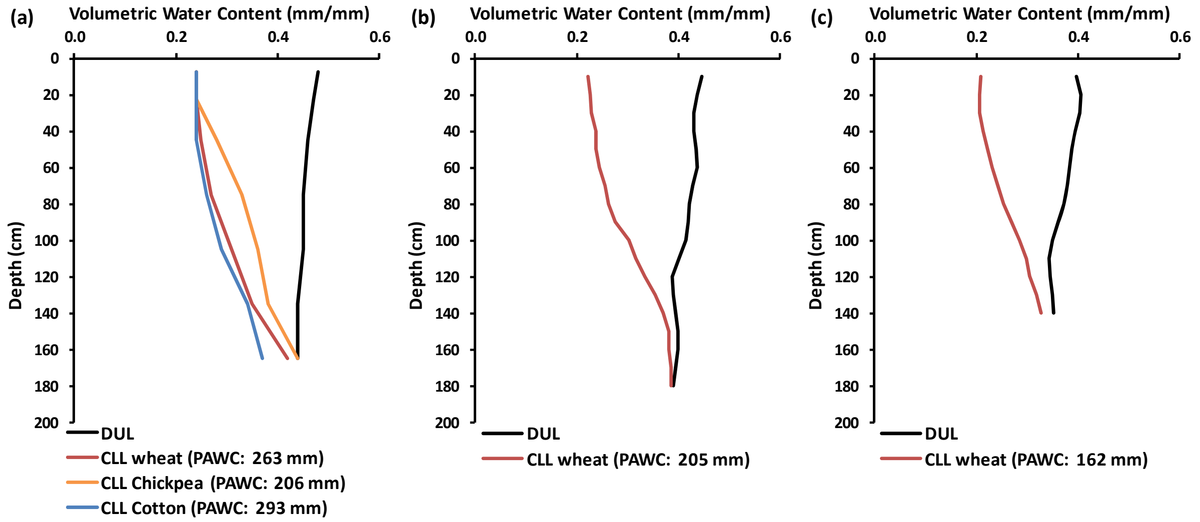


Figure 5. Select soils near Collarenbri (see (a), (b) and (c) below):

(a) Grey Vertosol (APSoil 126) near Merrywinebone in alluvial deposits. The high clay content (~60%) contributes to the high PAWC although the subsoil below 90 cm is affected by chloride and sodicity.

(b) Grey Vertosol MW51 near Collarenbri from the Profile Descriptions report. It has a strongly sodic subsoil although the report notes rooting to 175 cm.

(c) Grey Vertosol MW52 near Bullarah from the Profile Descriptions report. The report notes that dispersive subsoil may limit the penetration of water and reduce the effective rooting depth, but the PAWC of 162 mm may be an underestimate as characterisation was only down to 140 cm.

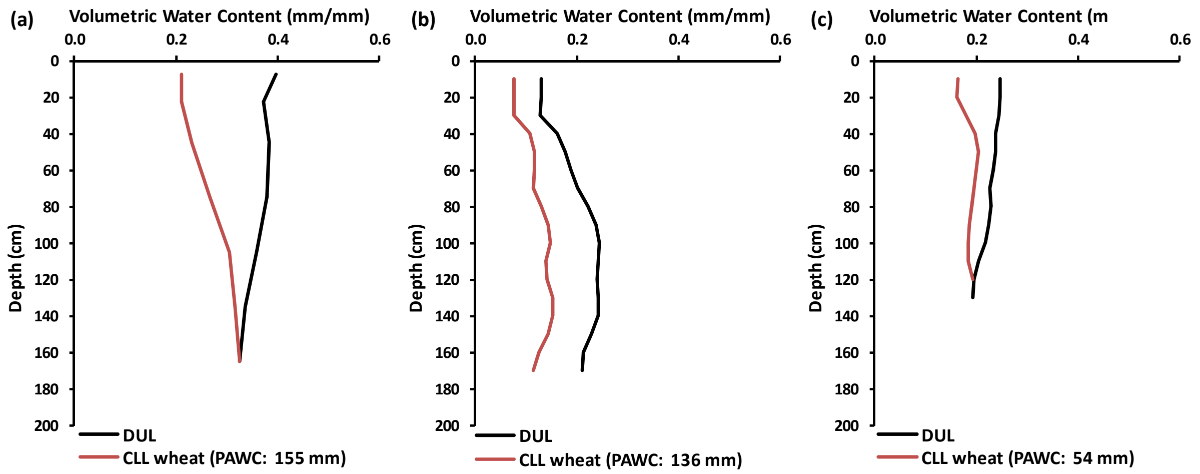


Figure 6. Select soils near Pilliga (see (a), (b) and (c) below):

(a) Grey Vertosol (APSoil 1014) just north of Pilliga and (judged by location in Google Earth) on alluvial deposits. The high clay content (58%) results in the higher PAWC compared with (b,c), but subsoil constraints (chloride and sodicity) reduce the PAWC from what it may have been based on texture alone.

(b) Red Chromosol (texture change (duplex) soil) North of Gwabegar (P56 from the Profile Descriptions report). The abrupt increase in clay % causes the shift and widening of the PAWC profile between 20 and 40 cm depth.

(c) Brown kandosol (structure less soil) north-east of Gwabegar (P57 from the Profile Descriptions report). Described in the report as being dispersive and poorly structured below 15 cm, the soil has a very low PAWC despite having a clay texture throughout.

Choosing an APSoil characterisation

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

- The nearest APSoil may not be the most appropriate as its soil, parent material and landscape position could be quite different (cf. Figure 6)
- Compare soil with descriptions of the APSoil sites (texture, colour, soil classification, chemical analysis). More recently collected APSoil characterisations include chemical analysis and particle size. As illustrated in Figures 4-6 both particle size and subsoil constraints strongly affect the PAWC.
- Dig a hole (soil auger, soil core, backhoe trench, roadside bank or cutting); note surface features (cracking, hard setting), subsoil issues (salinity, sodicity, etc), rooting depth. This can assist with APSoil selection as well as adapting an APSoil profile to local conditions (e.g. if depth of texture change or rooting depth is different).
- A measured sowing soil water profile (convert to volumetric) needs to 'fit' between CLL and DUL and can assist with APSoil selection (Figure 1b). If the measured (volumetric) water content profile is below CLL or above DUL then the texture of the soil does not match that of the chosen APSoil.
- Opportunistic CLL (e.g. soil core following a dry finish; convert to volumetric) can be compared with CLL of APSoil characterisations.
- Check for nearby soil survey characterisations (SoilMapp, Espade, Queensland Globe (see Resources section) and local soil reports) to help describe soils.
- Draw on soil-landscape mapping (where available) to find APSoil sites in similar landscape positions (see below).
- Native vegetation is often a useful indicator of soil type too and is indeed often included in information about soil-landscape, land resource area and land systems units.

Using soil –landscape information

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

In parts of NSW these soil-landscape units can be accessed through the ESpade tool (see Resources section), which delineates the units and provides a description and typical soil profiles for each unit (see Figure 7). In parts of Queensland, similar land resource area (LRA) mappings are used as part of land management manuals (see Figure 8). Where this information is available, it may be possible to use it to find an APSoil site in a similar landscape position as a first approximation of PAWC.

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

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

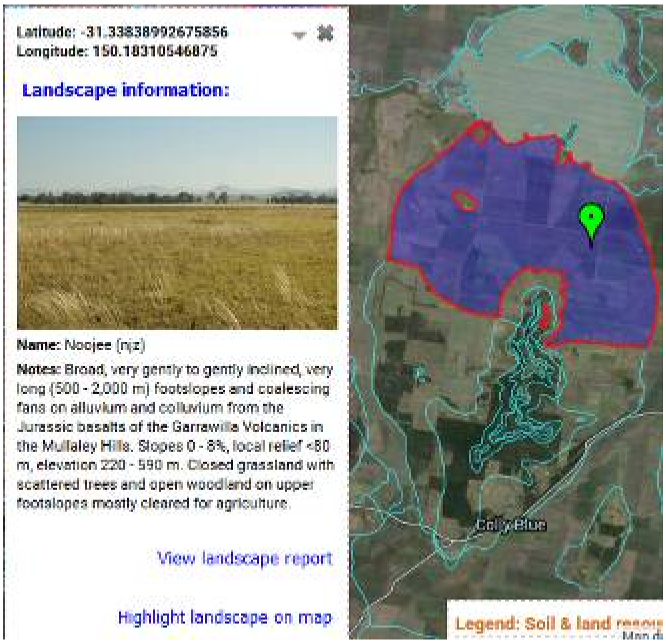


Figure 7. Example of soil-landscape mapping available for parts of NSW through ESpade. Mapping unit description is available through a pdf report and the landscape can be highlighted on the map

Figure 8. Section of Central Darling Downs with Land Resource Areas (LRA) delineated on Google Earth map with APSoil sites indicated. The accompanying description assisted in explaining the differences between some of the APSoil characterisations

Local soil and landscape mapping information

Walgett – Collarenbri – Pilliga

ESpade does not provide on-line access to soil-landscape mapping in this area and a draft map based on the 1:250,000 Walgett geology map only covers the south-western part of this region (south of Walgett and west of Come By Chance). A pdf copy of this draft can be found on http://archive.lls.nsw.gov.au/__data/assets/pdf_file/0004/495886/archive-walgett_map.pdf .

ESpade does provide higher-level land systems mapping for the western part of this region (north of Kamilaroi Highway and west of the Gwydir Highway). The pdf descriptions of the different land systems can provide some insights in typical floodplain components and their soil types.

Useful information about soils in the region is contained in the Profile Descriptions report by Daniells et al. (2002).

Acknowledgements
The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support. We also gratefully acknowledge the contributions of CSIRO colleagues and many collaborators and farmers to the field PAWC characterisations. Their feedback also helped prepare the list of 'tips and tricks'. The information on PAWC presented in this paper heavily draws on the work over many years by Neal Dalgliesh. Discussions with him and others, including with those involved with soil-landscape mapping in NSW (Neil McKenzie, Rob Banks, Brian Murphy and Neroli Brennan) were invaluable for the development of concepts and ideas presented in this paper. New characterisations in the Liverpool plains were supported by a group of consultants led by William Manning. We thank Sean Murphy for access to the Profile Descriptions report for

north-west NSW and its authors for the work involved with the PAWC characterisations and soil descriptions. Claire Yung provided assistance with the preparation of graphs.

Resources

APSoil, PAWC methodology and national information:

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

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

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

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

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

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

NSW:

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

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

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

Queensland:

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

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

References

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

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

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

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

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

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

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

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SoilWaterApp – a new tool to measure and monitor soil water

David Freebairn, University of Southern Queensland

Key words

Soil water, PAWC, soil type, decision making

GRDC code

USQ00014

Take home message

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

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

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

Background

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

The App

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

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

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

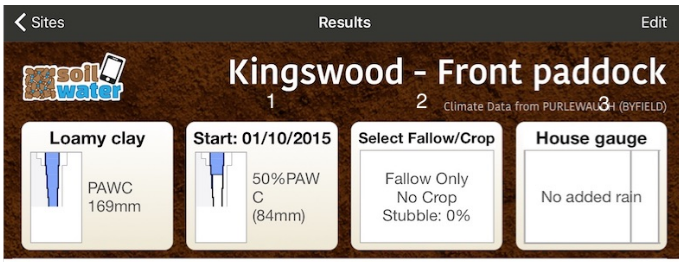

Figure 1. Screen allowing user to (1) set a start date and soil water distribution; (2) select the soil cover conditions for fallow or crop, and set crop plant and maturity dates; and (3) make additions to a local rain gauge if previously added.

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

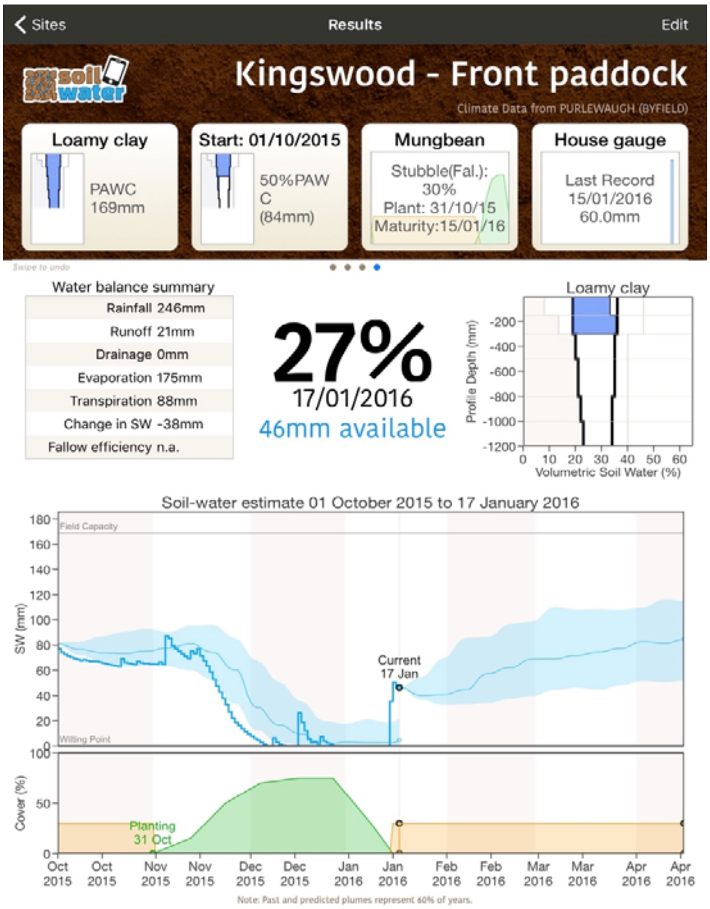

Figure 2. Results screen showing both text and graphics. Percentage of PAWC and mm water available take centre stage with the water balance and where the water is in the soil profile on either side. The graphic at the bottom of the screen shows the pattern of water accumulation, soil and crop cover.

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

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

Acknowledgements

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

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

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

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Accurate and efficient measurement of soil water in dryland systems: issues and experiences in replacing probes with EM38

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[3] CSIRO

Key words

soil moisture, EM38, capacitance probe, neutron probe, push probe, water use efficiency WUE, broad acre, dryland cropping

Take home message

- EM38's are a mobile soil moisture monitoring tool
- Removes the hassle of installing, maintaining and removing permanent probes
- Able to monitor soil moisture at multiple sites with the one device: ideal for large broad acre paddocks
- Fine tune WUE calculations and monitor water infiltration in soil

Forward

This summary out lines issues and experiences of using probes over several years on black cracking clays on a dryland broad acre farm, which employs contractors and casual staff. The EM38 has been widely used for recording conductivity variance across paddocks and only in recent years it has been modelled, by the CSIRO, as having a tight correlation to soil water. The EM38 is a scientific device and can be likened to a highly accurate quantitative push probe.

Capacitance and neutron probes are ideally designed for irrigation

- Probes are highly accurate tools used to measure soil water within close proximity of the probe site (1-10cm). This is great for smaller more uniform irrigation paddocks where you want to know how quickly the soil moisture is being used and when to schedule irrigation.
- These probes are usually installed post emergence in an area of uniform plant establishment and are able to settle into the surrounding soil after the first irrigation.

Issues with capacitance and neutron probes in dryland farming

- Dryland farmers want to know how much soil moisture they have prior to planting in order to make decisions on whether or not to plant. Thus the probe needs to be installed during the fallow.
- Probes work best when they are have settled into the surrounding soil. This increases the risk from damage to spray rigs, planting rigs and headers. Also operators have a tendency to drive around or lift over probes with planting rigs, which results in probe readings being inconsistent to the rest of the paddock.
- Capacitance probes are too expensive to be placed in every paddock in large broad acre farming systems yet for low rainfall years moisture status of each paddock is very important. While neutron probes are a lot cheaper they still require installing and time specific management during busy operational periods such as sowing and harvest.

- Farmers who are trying to measure accurate WUE want to know how much moisture is left at the end of each season. Paddock soil moisture is often estimated at the end of a crop cycle due to the properties of dry soil i.e. soil being air dried around probes as localised cracking forms or the inability to penetrate push probes through the dry top soil.
- Probe placement is subject to multitude of unforeseen variables such as localised runoff areas flowing to probe sites or vice versa running away.

Why change over to an EM38 to read soil moisture

- The EM38 readings have a tight correlation to capacitance and neutron soil moisture curves.
- Like probes, the EM38 requires a known range before the readings have any useful meaning i.e readings for wilting point and field capacity need to be recorded usually from a repeatable GPS location or certain soil type.
- In years where the profile is not at field capacity and there is doubt over sufficient stored water to grow a crop, the EM38 has the ability to measure what moisture has been stored: even in uneven cracked soils, which have been filled from the bottom up.
- An EM38 has the ability to take accurate readings anywhere in a paddock with the identical EM classification. This requires an EM survey map of the paddock along with known full and empty readings for that classified EM soil.
- As the EM38 is non-intrusive, there is a limitation to measuring the exact depth of the moisture front. The EM38 has two ranges 0-75cm and 0-150m, however holding the device above the ground at known heights can manipulate the depth of reading.
- In conjunction with an EM38 it can be useful verify readings against neutron probes and capacitance probes.
- The EM38 has the ability to give a tangible figure, which can be input into a spread sheet much like the probes.

Advanced use of EM38 in broad acre cropping

- As farmers strive for greater production and take-on farm based trials the EM38 is handy tool to measure differences in soil moisture between a trial and control – i.e. farmers questioning the infiltration rates in-between tram lines compared to the rest of the paddock as repeated harvest operations deposit strips of chaff behind the header.

EM38 in practice

- The EM38 is quiet daunting at first when trying to calibrate however there are several sources of information including PDF’s, YouTube and precision farming consultants.
- Calibrating readings for soil moisture should ideally be conducted with soil corer at the same time of readings.
- Leave device turned on when transporting between paddocks to avoid variations in readings while the machine is warming-up
- Familiarise yourself with the instruction manual for the do’s and don’ts of operating an EM38

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Fallow efficiency - what happens if stubble is concentrated in rows?

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Stubble impact on fallow water efficiency in western zones 2014/15

Lawrie Price and Brendan Burton, Northern Grower Alliance

Key words

Stubble, fallow efficiency

GRDC code

NGA00004, NGA00003

Background

The western cropping areas of North West NSW, eg the Walgett region, have had a run of consecutive low or patchy rainfall years that have reinforced the critical importance of maximising fallow water accumulation and conservation. However even under these patchy rainfall conditions, soil moisture levels under header trash trails were frequently sufficient to at least establish, and perhaps grow a crop.

In late 2013, the NGA Local Research Group at Walgett prioritised an issue to "help quantify what level of extra moisture could be accumulated under increased stubble loads". The intention was - if the scale of the moisture difference was sufficient - to then evaluate approaches to manage stubble residue in field that may allow cropping of 'zones' in the paddock.

The concept is really an extension of skip row style production, where stubble load is concentrated in the zones where the next crop will be sown.

Method

Two small plot 'proof of concept' trials were established in Jan 2014, near Walgett and Bullarah. Both trials were established in paddocks that had already been fallowed from wheat in 2012 but with a dry profile. Soil cores were taken to 120cm and split into 5 depths for gravimetric analysis.

The majority of treatments were imposed by adding straw at rates from 5 to 40t/ha with the straw held down by wire. One other treatment had the existing stubble removed by hand.

Table 1. Treatment description

Treatment	Groundcover (%)	Thickness of ground cover (cm)
Stubble removed	5	0
Untreated (standing stubble, ~ 3t/ha)	15	0
5 t/ha straw added	75	1
10 t/ha straw added	98	2
20 t/ha straw added	100	5
40 t/ha straw added	100	10

Bullarah: Photographs of key treatments (Soil type - grey vertosol)

Figure 1. Stubble removed (Start of trial, Jan 2014)

Figure 2. Standing stubble (Start of trial, Jan 2014)

Figure 3. Straw added at 5t/ha (Start of trial, Jan 2014)

Figure 4. Straw added at 10t/ha (Start of trial, Jan 2014)

Figure 5. Straw added at 20t/ha (Start of trial, Jan 2014)

Figure 6. Straw added at 40t/ha (Start of trial, Jan 2014)

Bullarah soil moisture results

An interim measure of moisture was made in both April & November 2014 using a push probe. Each plot was probed five times (April) or seven times (November), with the depth of soil moisture measured.

The April sampling was shortly after ~184 mm in late March. Figure 1 shows the differences in depth of wet soil between treatments. It is likely that the increased depth of wet soil under the added straw treatments was due to improved infiltration caused by the ground cover. There was little improvement in infiltration once the ground cover exceeded 75% (straw added at 5t/ha).

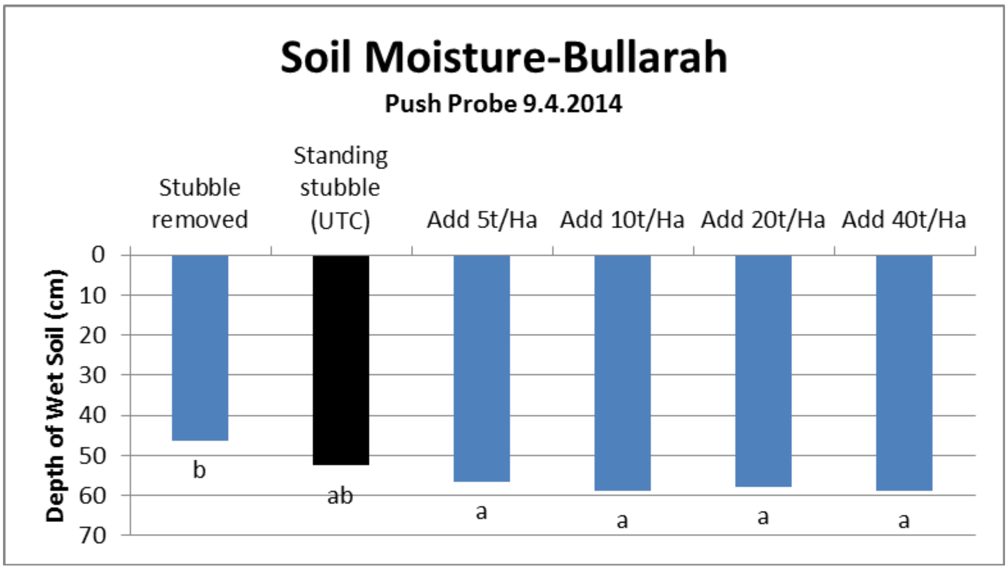

Figure 7. Depth of wet soil at Bullarah, April 2014

The second assessment in November 2014 was after a long dry spell (100mm in previous 7 months). The results indicated a reduction in depth of wet soil, presumably by evaporation, from the standing stubble or stubble removed treatments (see Figure 8). Where straw had been added, the depth of wet soil was similar to April 2014.

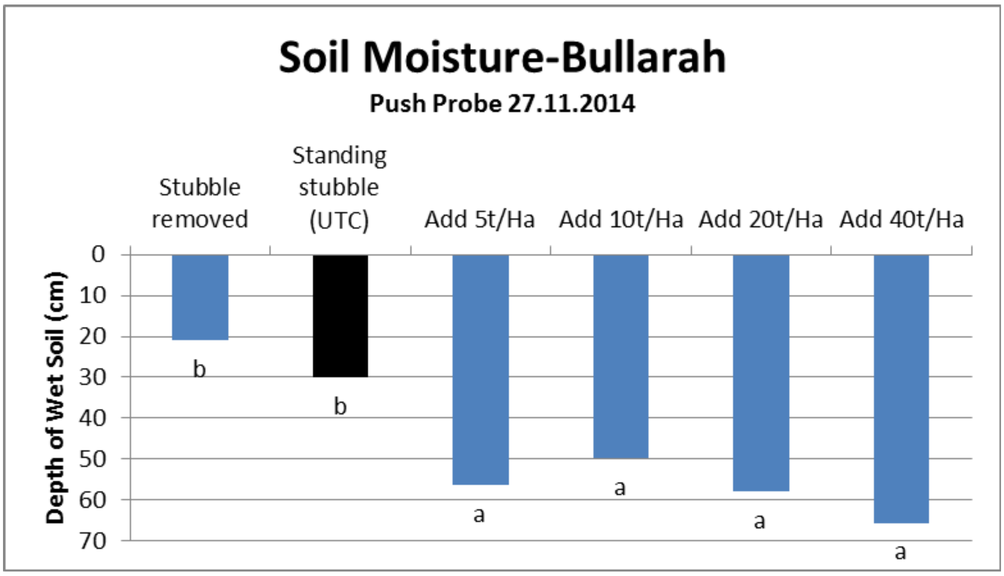

Figure 8. Depth of wet soil at Bullarah, November 2014

Final measurements of soil water were made in May 2015, this time measuring gravimetric water to 120cm to calculate both volumetric water and fallow efficiency. Figure 3 shows the volumetric results from deep coring and includes the starting moisture profile together with Drained Upper Limit (DUL) and the Wheat Lower Limit. Table 2 shows the fallow efficiency over the 16 months of the trial.

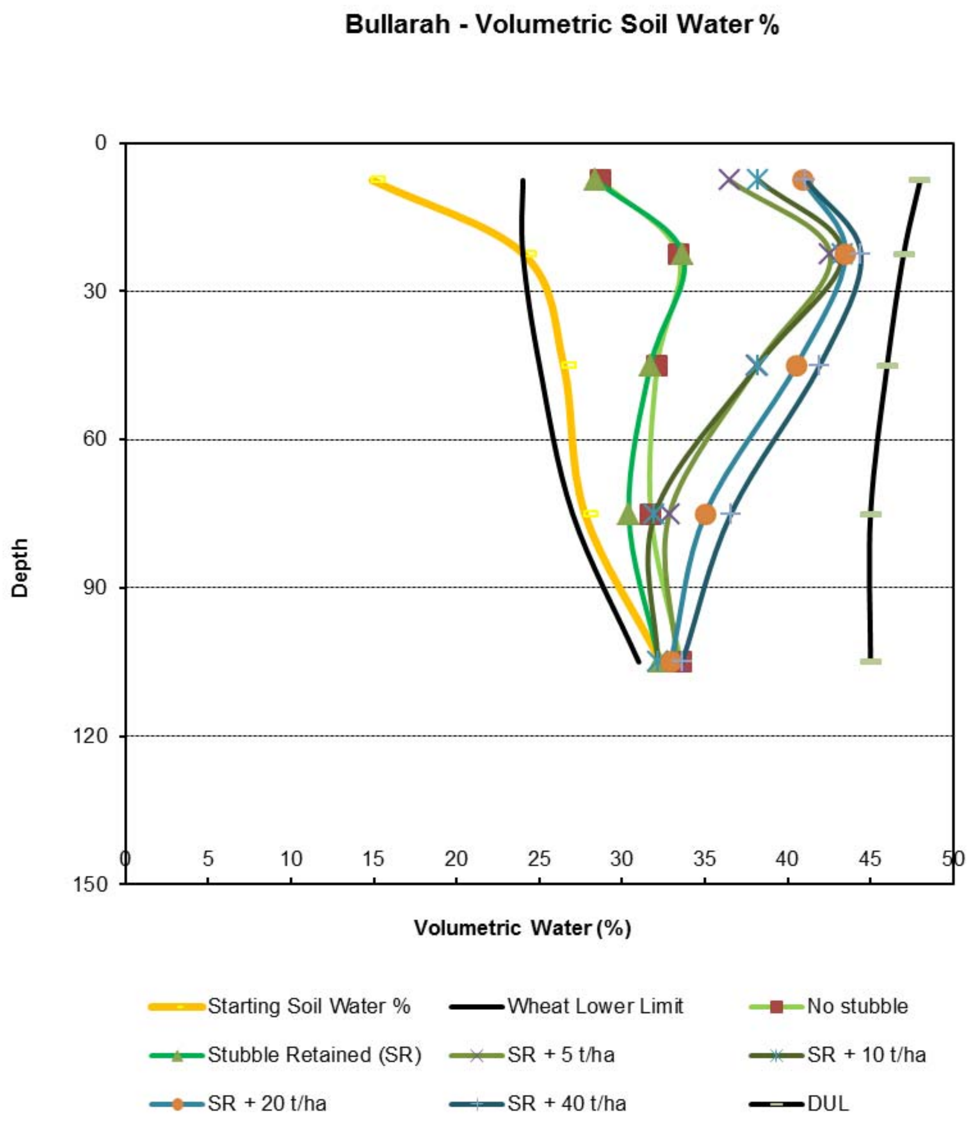

Figure 9. Volumetric soil water at Bullarah, May 2015

Table 2. Increase in available water and fallow efficiency over 16 month period

Treatment	Available Soil Water (mm)				Fallow efficiency (%)	
	13/5/2015		Water stored			
Stubble removed	66	c	55		10	
Standing stubble	57	c	46		8	
Additional 5t/ha straw	110	b	100		18	
Additional 10t/ha straw	109	b	98		18	
Additional 20t/ha straw	131	ab	120		22	
Additional 40t/ha straw	144	a	133		24	
P=	0.00					
LSD =	29.5					

NB Starting soil water, Jan 2014 = 11mm, total rainfall during trial = 551mm

Key points

- At this site there was little difference in amount of water stored or fallow efficiency between the stubble removed and standing stubble treatments.
- Significant increases in depth of wet soil and available soil water/fallow efficiency from all treatments with added straw
- Adding 5 or 10t/ha straw increased the available soil water by ~50mm and raised the fallow efficiency from ~9-18%
- Increasing the straw load from 5 or 10 to 40 t/ha significantly increased final available soil water, with the increase in water between 30-90cm soil depths ie deep moisture
- Suspected that some of the improvement in fallow efficiency was due to reduced evaporation because of the thick mulch layer.

Measurements of soil nitrogen were taken in May 2015. Surprisingly there were no significant differences between the treatments in total N kg/ha to 120cm. However between 0-15 and 15-30cm the stubble removed treatment recorded significantly higher nitrogen levels than all added straw treatments.

Soil samples were also analysed for *Pratylenchus thornei* from a subset of treatments. Mean numbers of *Pt* ranged from 6 to 10 *Pt*/g soil with no significant difference, although the lowest mean number was recorded under the 40t/ha added straw treatment.

Walgett results

The Walgett site has received less rainfall and the trial will continue. Push probing in April 2015 (15 months after the trial started) found 18cm of wet soil in the bare fallow and 39cm of wet soil in the 40 t/ha added straw treatment. The pattern was similar to the final available soil water at Bullarah, with a significant increase in depth of wet soil from all added straw treatments but an additional increase from the 20 and 40t/ha rates.

Conclusions

Too early to make a call but an encouraging level of benefit at the Bullarah site. Even if repeated, the issue will still be, can we create and manipulate straw/stubble loads to enable zone farming.

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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Planting date, row spacing and plant population impacts in wheat

Mick Brosnan & Jo Weier

Key words

cereals, planting date, row spacing, plant population

GRDC code

DAQ00162

Take home message

Yield penalties become increased with delayed planting dates so when faced with the decision to replant, a plant density of low populations can be more successful than replanting. Moisture seeking to plant on time achieves better results than waiting for a rain fall event and planting later than ideal. Narrow row spacing did not make any difference to yield so wide rows are fine if yield expectations don't exceed 3t/ha and provided you can control weeds

Background & aims

In order to answer questions relating to optimum plant population and planting dates for wheat Mungindi Cropping Group & DAFF initiated a trial comparing various plant populations and row spacing's over 2 planting dates. The trial was run over 3 years from 2012 to 2014.

Potential interactions between genotype, maturity, row spacing and planting dates were also looked at.

Trial setup

A series of trials were conducted in 2012, 2013 and 2014, on grey vertosol soils at Bullawarrie, North West of Mungindi. In 2014 an additional trial was conducted at another location south of Mungindi (Greentree). The aim of the trials was to determine timing, row spacing and plant population combination's that achieved the best yield outcome in two standard wheat varieties.

The following are the four treatment groups.

2 X Planting dates

- First week of May and first week of June.

2 X Cultivars (varieties)

- Gregory⊕, main variety in area, long season but can shorten up.
- Baxter⊕ 2012, Suntop⊕ 2013/2014. Common varieties for area. Good disease package. Slightly shorter season.

2 X Row spacings

- 25cm (10") and 50cm (20")

5 X Plant populations

- 7, 15, 30, 50, & 80 plants per meter. (no 7 in 2012)

Trials comprised four replicates of each treatment combination.

Results

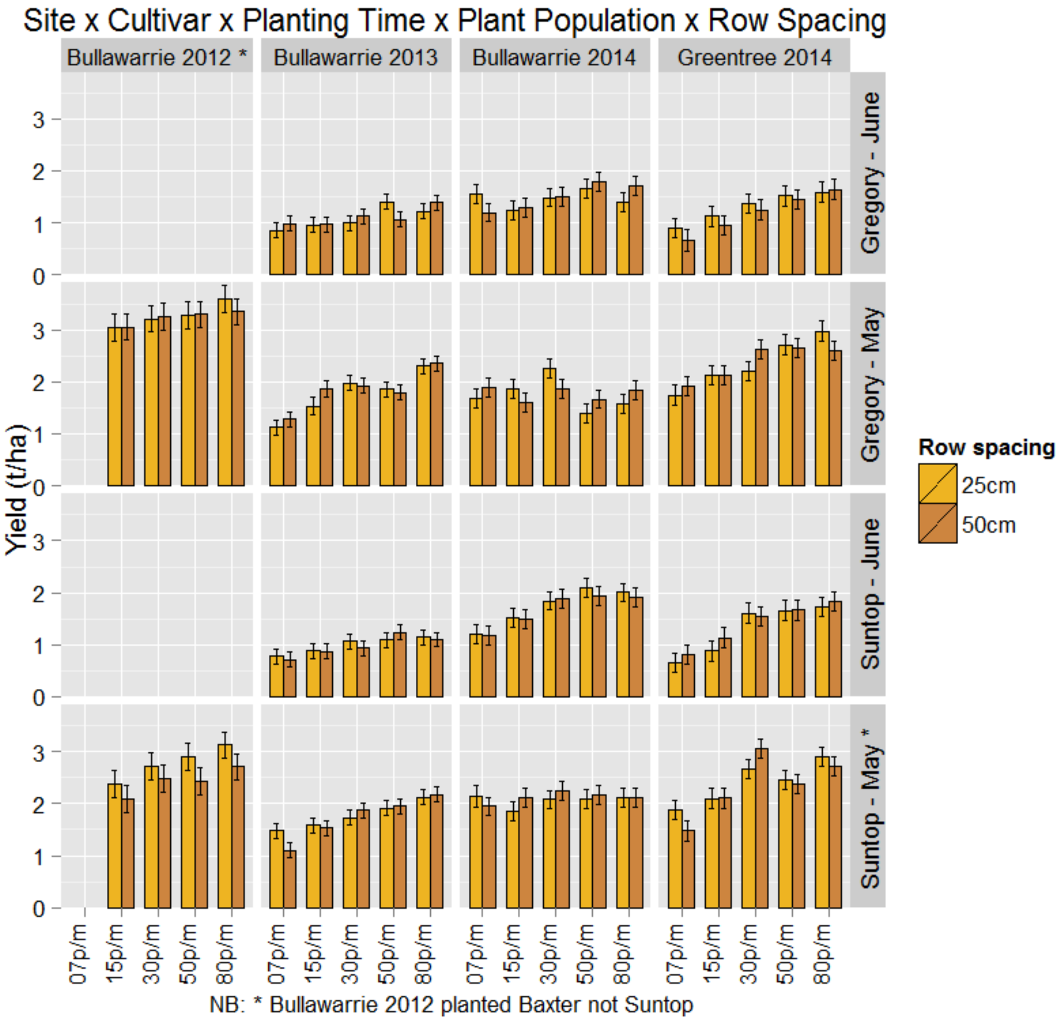

Figure 1. Full set of analysed means from the across sites analysis of Bullawarrie 2013, Bullawarrie 2014 and Greentree 2014 data. Analysed means of Bullawarrie 2012 are from individual trial analysis, note Baxter⦶ cultivar planted in 2012 not Suntop⦶.
* (only have early planting data for 2012 analysed)

In 2012 results indicate the higher densities of plant population showed significantly higher yields than the lower plant populations. The density of 80 plants/m was not significantly higher yielding than 50 plants/m, and 50 plants/m was not significantly higher than 30 plants/m, but all three of these densities showed significantly higher yields than the lowest density of 15 plants/m. The row spacing by cultivar interaction shows that the effect of row spacing is not consistent across the two cultivars. The difference in yields between the 25cm and 50cm row spacing of Baxter⦶ showed a greater difference in yield than what was displayed in Gregory⦶.

Site by planting time by plant population interaction

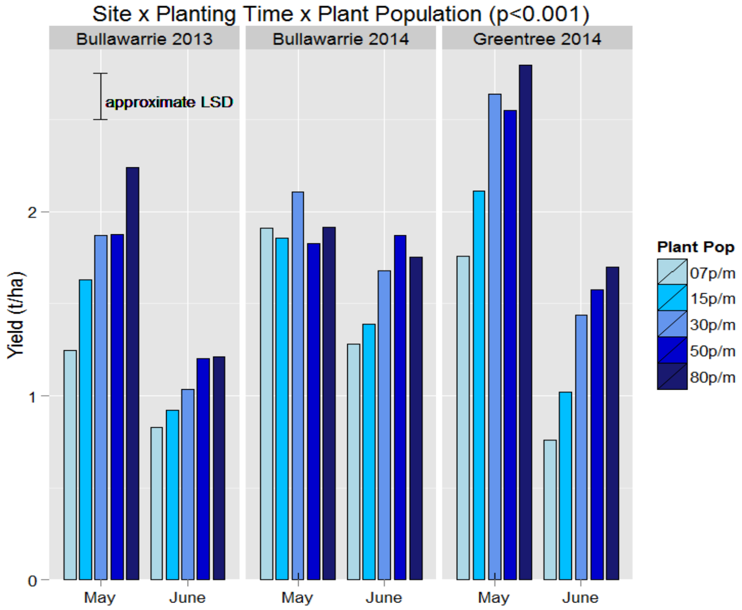

Figure 2. Analysed means from the site x planting time by plant population interaction

This interaction shows significantly higher yields in the May planting at the Bullawarrie 2013 and Greentree 2014 trials. Bullawarrie 2014 trial the yield benefit is not as evident.

Within each planting time, there was a significant gain in planting at higher densities as opposed to lower densities. The exception to this was in the early planting at the Bullawarrie 2014 trial, where the highest yield was achieved from the mid-range density (30 plants/m), but it was not significantly different to the lowest (7 plants/m) or highest (80 plants/m) density.

Site by cultivar by plant population interaction

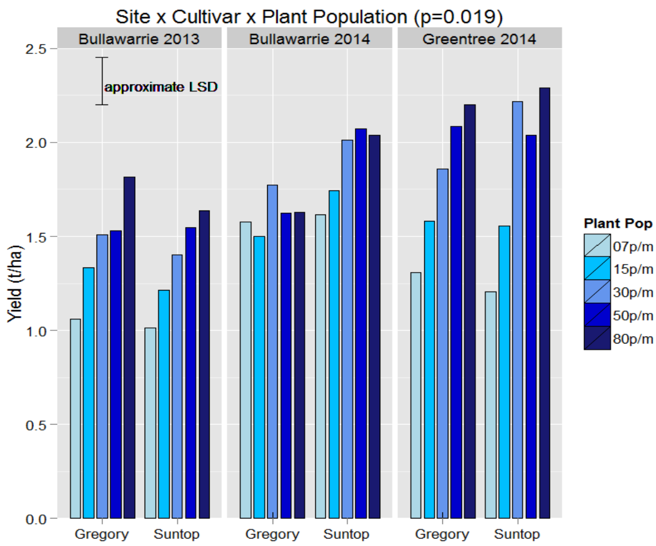

Figure 3. Analysed means from the site x cultivar by plant population interaction

This interaction shows that planting higher densities provided significantly higher yields across cultivars and sites, with the exception of Gregory in the Bullawarrie 2014 trial. For this cultivar at this site the yield at 30 plants/m was significantly higher than the yield at 15 plants/m, other than this, Gregory at Bullawarrie 2014 showed no significant difference in yield across the range of densities.

Cultivar by planting time by plant population by row spacing interaction

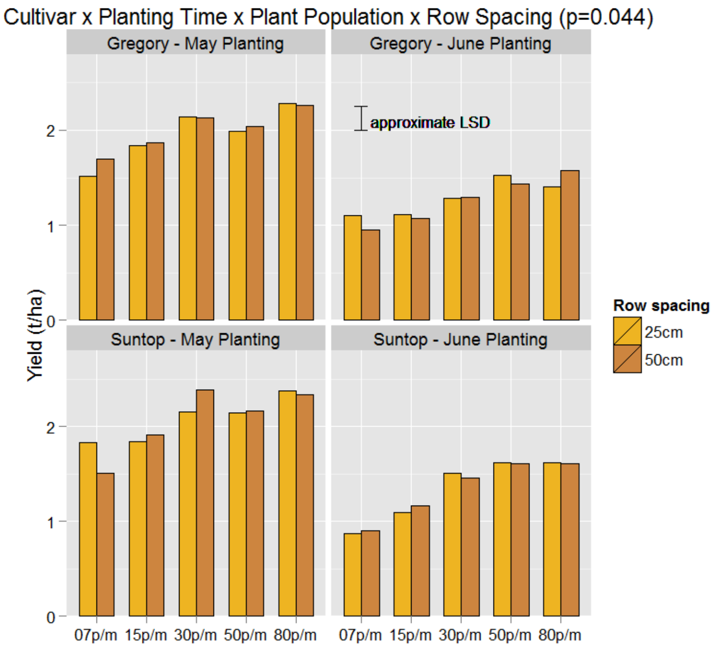

Figure 4. Analysed means from the cultivar by planting time by plant population by row spacing interaction

Results suggest that in an early planting of Suntop with low density, the 25cm row spacing would provide a higher yield than the 50cm spacing. The cultivar Gregory did not show the same effect. Apart from this difference in Suntop, there was no significant difference in yield between the 25cm and 50cm row spacings.

Results again suggest the maximum yield would be achieved in high density planting early in the season. Planting later in the season indicated lower yields than early season planting, however, within the later plating time the best gain to be made was still in planting high populations.

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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Data was analysed using a linear mixed model method

Northern winter pulse agronomy - Walgett - 2015

Andrew Verrell[a] *and Leigh Jenkins*[b]

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

Key words

faba bean, chickpea, plant density, nutrition

GRDC code

DAN00171 - Winter pulse agronomy project

Take home message

- Sow faba beans at 20 plants/m^2 in north-west regions
- Sow chickpea at 15 plants/m^2 in north-west regions
- Older cropping country is showing responses to applied P as well as Zn

Introduction

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

The Northern Winter Pulse Agronomy project had a range of experiments covering a number of agronomic themes in 2015. This paper reports on the outcomes of variety x density experiments for fabas and chickpeas and nutrition experiments in north-west NSW.

Faba bean – variety x plant density experiments

What did we do?

Faba bean, variety x density, experiments were conducted at three locations across northern NSW in 2015. Three varieties were sown; Doza⦶, PBA Warda⦶ and the new line PBA Nasma⦶. Four target plant densities were examined; 10, 20, 30 and 40 plants/m^2. All five trials were grown under dryland cropping conditions.

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

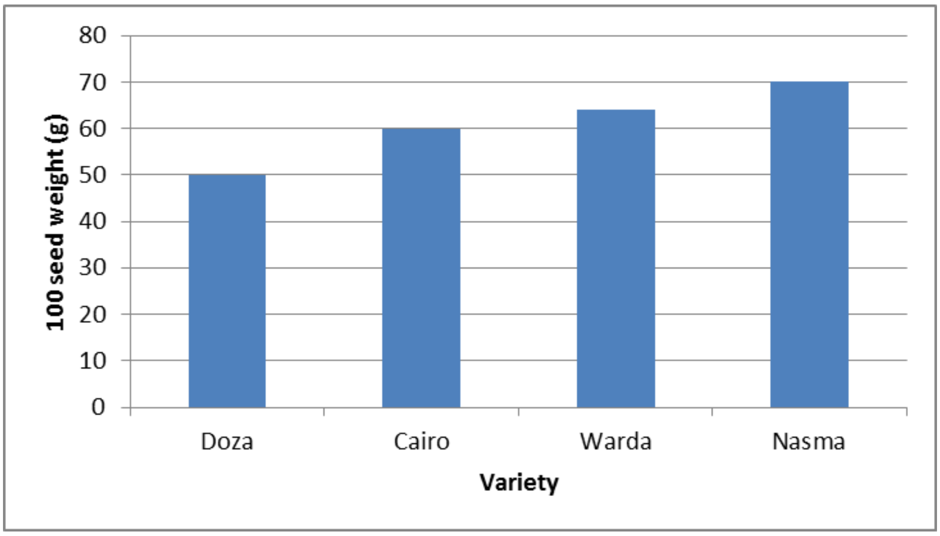

Figure 1. Average 100 seed weight (g) for selected faba bean varieties (Varieties Dozaᶲ, Cairoᶲ, Wardaᶲ and Nasmaᶲ shown in the graph above are protected under the Plant Breeders Rights Act 1994)

What did we find?

For grain yield, there were no significant interactions between variety and plant density, only main effects (see Table 1). PBA Wardaᶲ and PBA Nasmaᶲ out yielded Dozaᶲ at Coonamble, with no significant difference in varieties at Bullarah or Cryon (Table 1). Grain yield had a significant response to plant density at Cryon, plateauing at 20 plants/m^2.

Table 1. Faba bean grain yield (kg/ha) for the main effects, variety and plant density at three locations in 2015

	Grain yield (kg/ha)		
Variety	**Bullarah**	**Coonamble**	**Cryon**
Dozaᶲ	1602a	2900b	1547a
Wardaᶲ	1687a	3280a	1700a
Nasmaᶲ	1685a	3452a	1686a
	Grain yield (kg/ha0		
Plant density (plants/m^2)	**Bullarah**	**Coonamble**	**Cryon**
10	1498a	3376a	1373b
20	1670a	3411a	1772a
30	1768a	3246a	1673a
40	1666a	3270a	1745a

Values with the same letter are not significantly different P=0.05

Chickpea – variety x plant density experiments

What did we do?

A series of chickpea variety x plant density factorial experiments have been conducted across north western northern NSW from 2011 to 2015.

Varieties examined were PBA HatTrick⦶, PBA Boundary⦶, Kyabra⦶, CICA912 and CICA1007 at plant densities of 5, 10, 15, 20, 30 and 45 plants/m^2. During 2011, 2012 and 2013 experiments were located at Coonamble and at Spring Plains in 2014 and Rowena in 2015.

Across all sites and years variety and plant density were significant as main effects but there were no significant interactions between variety and plant density except in 2015 at Rowena.

What did we find?

At Rowena in 2015 there was an interaction between variety and plant density (see Figure 2). Kyabra⦶ outperformed all cultivars at 5 plants/m^2 plateaued, between 10-15 plants/m^2, then declined in yield as density increased. All varieties had similar trends, except PBA HatTrick⦶ which peaked in grain yield at 30 plants/m^2. Kyabra⦶ has been a consistent performer in this region in terms of grain yield.

The plot of grain yield versus plant density for different locations over the last five years is shown in Figure 3. The response of yield to plant density was flat from 15 to 45 plants/m^2 (see Figure 3) for most years. The high yielding response at Coonamble in 2011 was due to a high rainfall year (381mm) while the other years received less than 150mm.

Densities below 15 plants/m^2 can expose crops to severe yield loss due to virus and very low density crops have an increased tendency to lodge with branches breaking and pods on the ground.

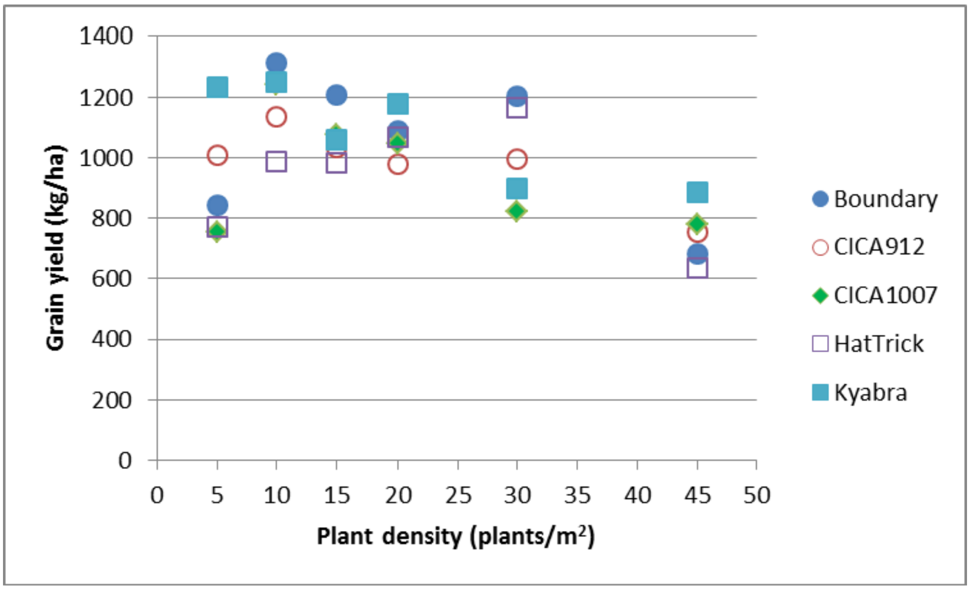

Figure 2. Effect of Chickpea variety x density on grain yield (kg/ha) at Rowena for 2015 (Varieties PBA Boundary⦶, Kyabra⦶ and PBA HatTrick⦶ shown in the graph above are protected under the Plant Breeders Rights Act 1994)

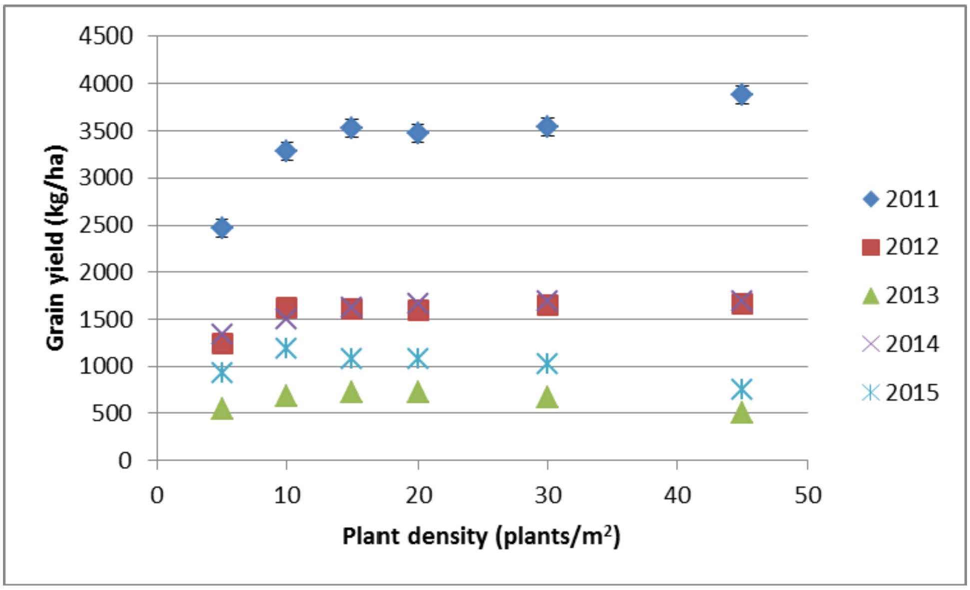

Figure 3. Effect of plant density on grain yield (kg/ha) at Coonamble (2011, 2012, 2013), Spring Plains (2014) and Rowena (2015)

Chickpea nutrition

What we did?

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

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

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

PBA HatTrick⚓ was sown at all sites at 30 plants/m^2.

What we found?

Grain yield data for the four experimental locations is contained in Table 2.

In 2014 responses were in-conclusive with a negative yield response at Coonamble from applying a full set of nutrients. In 2015, Rowena showed no significant responses to applied nutrients. However, at Coonamble in 2015 there were responses. The 2015 Coonamble site showed grain yield responses to applied Zn (by 7%), applied P (by 4%) and Fe (by 8%). The Coonamble site, a grey-brown vertosol lies east of the town and has been cropped since the early 1960's.

Table 2. Effect of selected nutrient omission treatments on grain yield (kg/ha) in chickpea at northern NSW sites

Treatment	Coonamble 2015	Rowena 2015	Spring Plains 2014	Coonamble 2014
Minus-Zn	1816b	788a	1427 b	770a
Minus-P	1864b	986a	1553 a	787a
Minus-Fe	1804b			
All	1947a	1019a	1479ab	654b

Values with the same letter are not significantly different P=0.05

Conclusion

Limited data from the first year of trial results in 2015 suggests that for northern and western sites 20 plants/m^2 is a preferred target plant density for faba beans.

Large seed in faba beans does not necessarily confer higher yield

For chickpeas, when sowing within the optimum sowing window mid May – mid June, sow at 15 plants/m^2

Older cropping country is showing responses to applied P as well as Zn and Fe

Acknowledgements

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

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Role and fit for dual-purpose crops for mitigating risk and optimising profit in low rainfall western grain growing regions?

Lindsay Bell, CSIRO Toowoomba

Key words

cereals, grazing, economics, soil water

GRDC code

CSP000132, Grain & Graze 2

Take home message

The flexibility to make use of grazing from grain crops opportunistically can help manage climate and price fluctuations and maximise potential returns across years.

Long-season dual-purpose cultivars could provide significant biomass for grazing and when well managed potential economic advantages of >$400/ha compared to current grain-only systems.

Wide sowing window of winter cultivars (e.g. Wedgetail⟨Ⓟ⟩, Revenue⟨Ⓟ⟩) could enable early sowing opportunities to be used without high risk of frost.

Opportunistic grazing of current spring 'grain-only' varieties is possible but they provide less grazing and economic benefits from graze + grain is less ($0-200/ha)

Under certain price and climatic conditions it might often be more profitable to graze a crop than to continue on to harvest grain

Critical yields to sacrificial graze are likely to be most profitable around 1.2-1.5t/ha, but it is difficult to forecast these situations early in the season based on soil water.

Introduction

Dual-purpose use of grain crops offers the potential to improve the flexibility and resilience of mixed farming systems. Analysis of experimental data has shown that utilising winter cereals (wheat, barley and triticale) and canola for a period of grazing during their vegetative phase before allowing the crop to regrow to produce grain yield (graze + grain), can increase the net returns from that crop by 25-75%. This has been traditionally done with longer-season winter cereals, but research is now showing there is potential to use shorter season spring varieties in the same way, but they provide less grazing due to the shorter duration of their vegetative phase. In many situations and if grazing is managed correctly, the grazed crop can produce similar grain yields to an ungrazed crop, though it appears that the economic optimum is to graze to a level that incurs a yield penalty of 10-20% compared to an ungrazed crop. In addition to graze + grain uses of cereals there is often situations where sacrificially grazing grain crops with low yield prospects can be more profitable than continuing to harvest grain. Both these opportunities for dual-purpose grazing can provide valuable high quality winter forage, flexibility to use the crop for continued grazing, hay or silage or grain production and the use of longer-season varieties also widens sowing windows. This paper provides some simulation analysis of the potential fit and productivity of dual-purpose wheat in the lower rainfall districts of northern NSW. It will also examine the potential to tactically graze winter cereal crops and sacrifice grain yield when prospects are poor.

Widening sowing windows

One of the major advantages of winter varieties suited to dual-purpose graze + grain are their capacity to be sown over a wide period and vernalisation controls the timing of flowering to occur at a consistent time of the year. Using historical climate information, an analysis of the frequency of sowing opportunities in fortnightly windows from March to June at Walgett shows that there are often unutilised opportunities during March and April before the opening of the main wheat sowing window. Sowing opportunities are calculated in two different ways here: 1) the first is when the rain received exceeds the potential evaporation over 7 days; this was found to closely correspond with sowing dates for winter crops across Australia and accounts for the fact that more rain is required to trigger a sowing opportunity in March than in May because the evaporation rates are higher. 2) the second is just using a threshold of 15 mm of rain occurring over a 7 day period. This analysis also demonstrates that a sowing opportunity in mid to late May only occurs in 40-50% of years, hence capacity to utilise earlier sowing opportunities on a proportion of the farm to reduce risks of missing later opportunities and reduce pressure on planting machinery availability during the main crop sowing window.

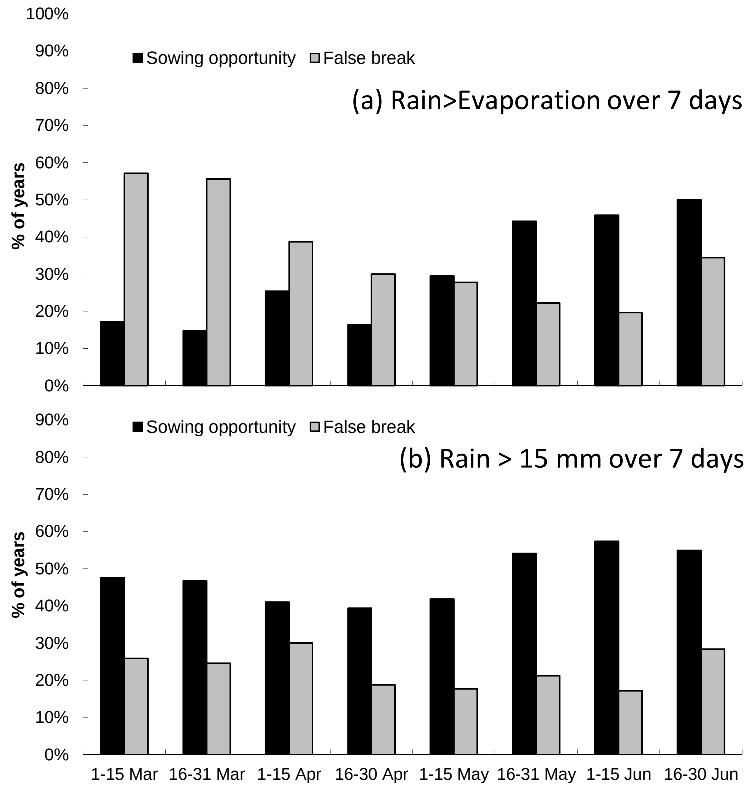

Figure 1. Frequency of a sowing opportunity in fortnightly windows from 1 March to 30 Jun at Walgett. Sowing opportunities were calculated as the % of years when either (a) rainfall exceeded potential evaporation over a 7 day period or (b) when 15 mm of rainfall over a 7 day period.

Potential of graze + grain use of wheat

Figure 2 shows potential grain yields and available biomass for grazing in mid-July from simulations of 3 wheat varieties across a range of possible sowing dates at Walgett. Simulations here assumed the crops were provided with adequate N in the soil throughout the crops growth and a crop was sown on that date irrespective of soil water which had accumulated over a short-fallow following a previous winter crop (average 90-120 mm PAW at sowing).

This shows that the simulated grain yield potentials for a shorter-season winter type variety like Wedgetail is similar to that for a spring wheat like Gregory; median simulated potential grain yields were 3.0-3.5 t/ha. Both varieties are exposed to similar range of variability in grain yields. The predicted yields for a longer-season winter variety like Revenue are lower, due to its later development causing a higher likelihood of water stress during grain filling. Simulations suggest that a well fertilised winter varieties could grow around 5 t DM for grazing by stem elongation. Much less grazing potential could be obtained from spring varieties, 1000-2000 kg of DM for grazing by stem elongation in Gregory⦷.

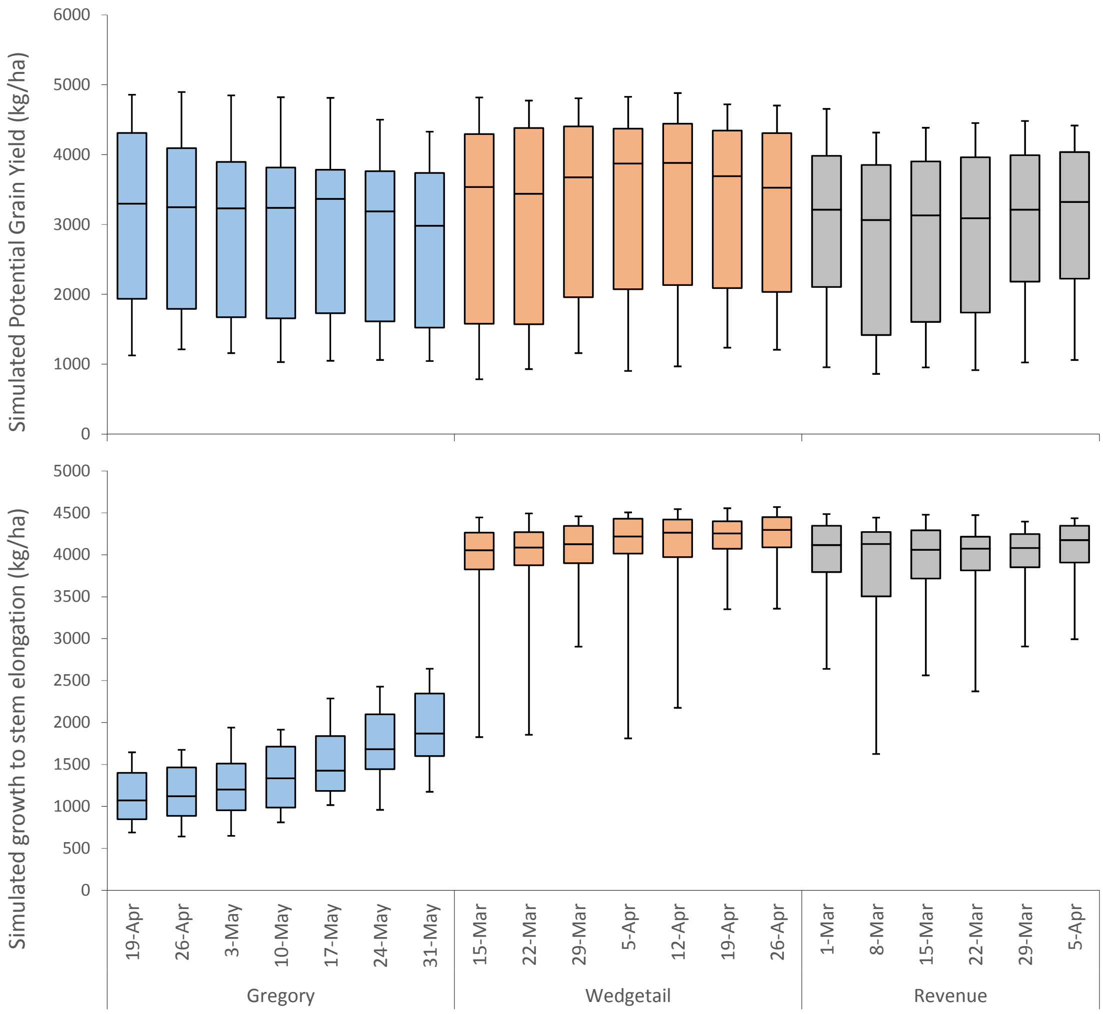

Figure 2. Long-term simulated potential grain yield (top) and biomass available for grazing prior to 15 July (bottom) for Gregory⦷, Wedgetail⦷ and Revenue⦷ sown on different dates at Walgett.

A simple economic analysis using these simulated grain yields and biomass grown by stem elongation is shown in Fig 3. This analysis assumed a yield penalty of 15% from grazing a crop and a grain price of $270/t, and the biomass growth was converted into livestock returns assuming 20 kg allowance per animal (cattle) per day with a daily live-weight gain of 1.2 kg per day and a price of $1.80/kg LW. The estimated returns were compared to a grain-only Gregory⦷ crop sown on 10 May each year. This shows that the potential increase in returns from a graze + grain use of a spring wheat crop is around $50/ha ± $70/ha. Predicted returns are much higher from the longer season wheat crops – the median economic advantage was around $200-450/ha in Wedgetail⦷ and $100-380/ha in Revenue⦷. This suggests that even livestock production levels half of those assumed above or yield penalties of >40% would be required before these dual-purpose wheat crops would fall behind the grain only crop.

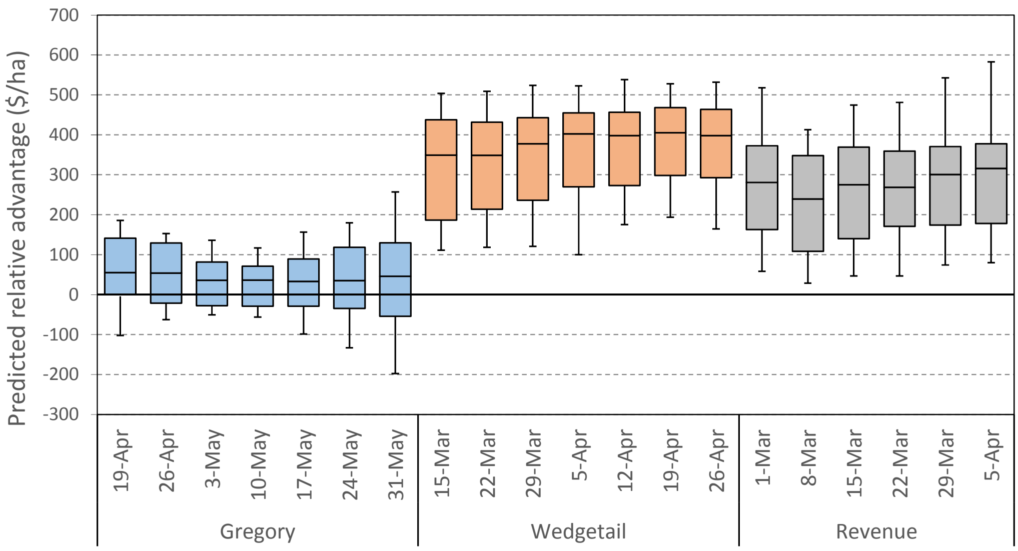

Figure 3. Predicted economic advantage of dual-purpose graze + grain for Gregory, Wedgetail and Revenue sown on different dates at Walgett compared to a Gregory grain only crop sown on 10 May each year. Dual-purpose crop economic assumed a grazing allowance of 20 kg per animal per day, a daily liveweight gain of 1.2 kg per day per animal and a price of $1.8/kg LW and grain yield was reduced by 15%; grain price was assumed to be $270/t.

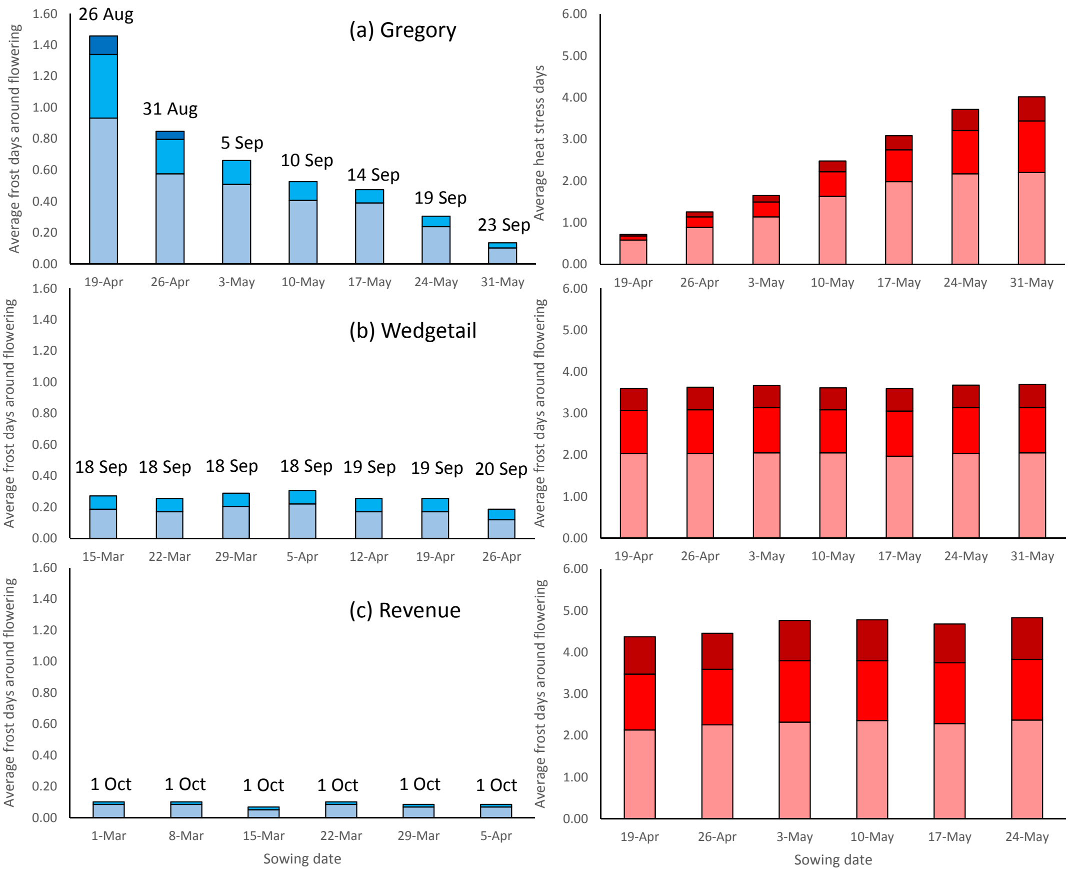

Figure 4. Long-term analysis of average flowering date, and average number of mild (0-+2°C), moderate (-2-0°C), and severe (<-2°C), frost (left) and mild (32-34°C), moderate (34-36°C) and severe (>36°C) heat stress (right) events during flowering and early grain filling for a range of sowing dates for Gregory, Wedgetail and Revenue at Walgett.

The simulations predict potential crop yields and do not take into consideration losses due to frost or heat stress events. Figure 3 shows the likelihood of these events for the different simulated sowing dates for the 3 winter wheat varieties above. This demonstrates the clear difference between the spring and winter varieties in flowering date response to sowing date, with average flowering date in Wedgetail around 18-20 September and Revenue flowering on 1 Oct across all sowing dates. This later flowering of Revenue exposes it to higher risks of high temperature events during flowering. This flowering time for Wedgetail corresponds to a similar flowering date to a crop of Gregory sown in late May. The analysis shows that Gregory sown prior to late April is exposed to increasing risk of frost events. If sowing before this a winter variety like Wedgetail could replace a spring variety in order to avoid high frost risk during flowering.

Tactical sacrificial grazing – is it an option and when?

A further option in addition to grazing grain crops with the plan to lock them up to produce grain is to graze a crop later into the season and sacrifice grain yield. This is likely to be a valuable approach in dry seasons when other forage sources are also in short supply and when grain yields are likely to be low. Here comparisons are made between the amount of biomass produced by a crop at flowering and estimating the potential grazing return from that compared to a crop when only grain is harvested.

Grazing return = *Flowering biomass* X 50% utilisation X 0.1 kg LW/kg forage consumed x **Price**

Grain return = *Grain yield* x *Grain price* - $35/ha harvesting costs

An analysis across an east-west transect along the NSW/Qld border shows that the frequency that a grain crop has more value for grazing is higher in the drier western locations (e.g. Mungindi) than at Warialda. Soil type can all have a significant influence with soils with lower PAWC likely to run out of water more frequently and hence convert early crop biomass poorly to grain yield (Table 1).

Table 1. Proportion of years when grazing a wheat crop is more profitable than continuing to harvest at 3 locations in northern NSW on soils with different plant available water holding capacity (PAWC). Analysis assumed wheat was sown on the first opportunity each year and a grain price of $270/t and $2.0/kg LW for livestock.

	PAWC (mm)		
Site	**240**	**180**	**120**
Mungindi	0.39	0.40	0.67
Goondiwindi	0.23	0.23	0.44
Warialda	0.18	0.21	0.46

Table 2 examines the effect of soil water at sowing on the likelihood that a crop could have higher value if sacrificially grazed. This shows that crops sown on low levels of soil water will have the highest likelihood of this but crops still sown with higher soil water this is still a frequent occurrence (over 50% of years at Mungindi).

Table 2. Effect of soil water at sowing on frequency that sacrificial grazing is more profitable than harvesting for grain. Analysis assumed a grain price of $270/t and $2.0/kg LW for livestock.

	PAW at sowing (mm)							
Location	**0**	**25**	**50**	**75**	**100**	**150**	**200**	**240**
Moree	75	65	63	55	55	45	35	6
Mungindi	84	67	69	69	67	59	49	6
Warialda	65	55	49	45	41	31	27	14

The relative prices of grain and livestock have a large influence on the likelihood that sacrificially grazing a crop is a more profitable alternative to continuing for grain. Table 3 below shows that if grain prices are > $250 per tonne and livestock prices are below $1.60/kg LW then it is unlikely that grazing a grain crop will achieve greater returns. However, if livestock prices are more attractive then this could be an alternative to consider.

Table 3: Grain & livestock price effects on % of years that a wheat crop is more profitable than harvesting at Mungindi. Grazing calculated using a utilisation of 50% of biomass at flowering and a feed conversion rate of 0.1 kg LW/kg forage consumed.

Delivered Grain price ($/t)	**On-farm livestock price ($/kg LW) 1.2**	**1.6**	**2**	**2.4**
200	13	58	78	88
250	4	18	55	73
300	3	4	20	54
350	3	3	5	20

Finally, Figure 5 below shows the relationship between grain yield and the relative difference in grain and grazing returns from a crop. This shows that the likelihood of grazing being more profitable is in years with lower grain yields. The line indicates the critical grain yield at which grazing a crop is more likely to be more profitable than continuing to harvest grain; at Mungindi under grain prices of $270/t and livestock prices of $2.0/kg LW this critical yield is around 1.2-1.4 t/ha. Analysis of this against soil water indicators through the season shows a poor relationship, suggesting it is difficult to identify early seasons when sacrificial grazing might be an option. Nonetheless, a combination of seasonal forecasts, current soil water status and expected crop yield could be used to provide information on the likelihood that sacrificially grazing a crop is a more profitable option.

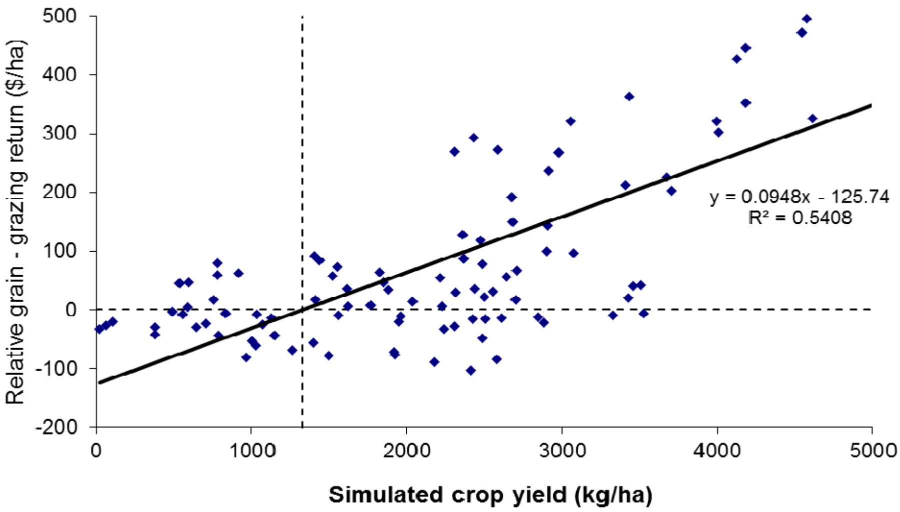

Figure 5. Relationship between final crop yield and relative returns from grain or grazing crop (harvesting grain is more profitable when above the line). This can be used to predict a critical grain yield below which is more profitable to graze a grain crop than continue to harvest.

Challenges of grazing to utilise of dual-purpose crops

One of the greatest potential difficulties for maximising the potential returns from grazing crops, either graze and grain or sacrificial grazing, is the capacity to apply sufficient stocking rates to utilise the forage in the narrow window available. In southern Australia, stocking rates of > 25 DSE or > 8 adult cattle equivalents per ha are used to sufficiently graze rapidly growing cereals. A brief example below I hope will demonstrate the challenge for evenly utilising dual-purpose crops in regions where fields are typically large. Let's say an early sown wheat crop had 2.5 t DM when you want to start grazing in early June and it is likely to grow at 50 kg of DM/ha/day for the next 6 weeks during which you want to graze it to leave a residual of 1-1.5 t DM/ha (i.e. about 3-3.5 t DM is available for grazing). Assuming an allowance of 2 kg of DM per DSE per day this would require a stocking rate of > 37 DSE/ha over this 6 weeks. So if you had a 50 ha field this would require around 2000 DSE to utilise this forage effectively.

For graze + grain crops, one alternative to the above scenario is to graze at lower stocking rates (<10 DSE/ha) and allow a longer grazing period. This has been applied in the low rainfall wheat-belt of Western Australia where light grazing pressures or 'clip' grazing even past crop growth stage 30 (jointing) was shown to have little or no detrimental impact on crop yields compared to ungrazed crops.

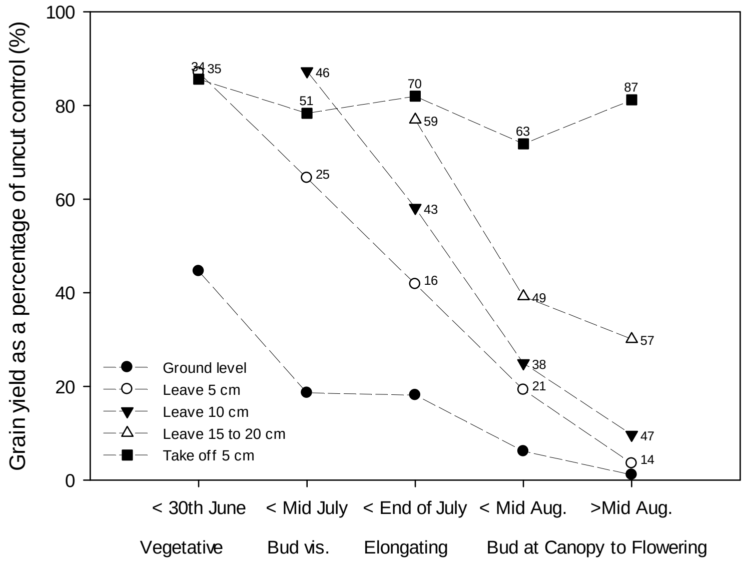

Figure 6. Grain yield recovery of canola crops defoliated at different intensities and timings in the Western Australian wheat-belt (Source: Seymour et al. 2014) showing that light defoliation even later in the season after 'safe' lock-up can have only moderate impacts on crop grain yield recovery. Numbers indicate the residual biomass as a % of the control at that time.

Opportunities in other crops

The examples provided above mainly focus on the dual-purpose use of wheat, but there are several other crops where the same principles apply. For graze and grain use there are winter and spring cultivars of canola, barley and triticale which can provide similar benefits to those specified here in wheat. Similarly, several other crops can have multiple uses in a similar way to the sacrificial grazing ideas here. In addition to those species listed above, field pea, soybean, and several millet cultivars could be harvested for grain under favourable seasonal conditions or grazed or harvested for forage if conditions are less suited to grain production.

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Sowthistle – update on glyphosate resistance survey, and overview of resistance testing and management options

Annie van der Meulen, Michael Widderick, Tony Cook, John Broster

Key words

Common sowthistle, milkthistle, glyphosate, herbicide resistance

GRDC code

UQ 00062

Take home messages

- Common sowthistle populations in the northern region have developed resistance to glyphosate.
- Survey results indicate that glyphosate resistant sowthistle populations are concentrated in northern NSW.
- An integrated approach to managing common sowthistle is recommended to prevent seed set and combat herbicide resistance.
- Herbicide resistance testing is recommended as part of an integrated weed management (IWM) strategy.

Survey of glyphosate resistant sowthistle in the northern region

In the northern region, glyphosate is a highly important herbicide for controlling common sowthistle in fallows. However, in 2013/2014, two populations of common sowthistle (*Sonchus oleraceus*) from northern NSW were determined to be glyphosate resistant.

To establish how abundant and widespread this resistance is across the northern cropping region of Australia, the Queensland Department of Agriculture and Fisheries (DAF) are leading a glyphosate resistance survey of common sowthistle across the region. The research is being conducted in collaboration with the NSW Department of Primary Industries (NSW DPI) and grower solutions groups including the Northern Grower Alliance (NGA) and the Grain Orana Alliance (GOA).

Because the survey objective is to determine the abundance and distribution of glyphosate resistant sowthistle populations across the northern region, it was decided not to bias sampling by specifically targeting “problem” sites or survivors of glyphosate application, leading to an over-estimation the incidence of resistance. To sample as many populations as possible, the decision was made to collect from sowthistle plants growing within both fallow and cropping situations.

Volunteers, mostly local agronomists and some farmers, have assisted in the survey by collecting seed samples, and this has been shown to be a very effective way of sampling the large study area. To ensure that high quality sowthistle seed samples are collected, a “collection kit” was prepared by the research team, which was sent to each seed collector. This kit included a detailed sampling protocol, numbered calico sample bags, and postage-paid, pre-addressed packages for sending the seed samples in for testing. Common sowthistle germinates in any season and can flower all year-round, provided there is adequate soil moisture. If there has been a significant rainfall event within recent months, seed producing plants are likely to be found in many crop and fallow paddocks. With their in-depth local knowledge and easy access to cropping properties, local agronomists and farmers can be on-the-spot to collect seed samples when the time is right.

In brief, the protocol for seed sample collection is as follows:

- Sites need to be cropping properties, located a minimum of 5 km apart.
- The paddock edges should be avoided in sample collection.
- Collect seeds from at least 20 individuals per site sampled.
- Record details of the sample population, including GPS location, on the field data sheet provided.

Once received for testing, the seed samples are stored in a dehumidified cold room at the Leslie Research Facility, so as to preserve seed viability until the time of their inclusion in screening tests. Before going into storage, they are sorted to assess quality, and to remove seed eating insects.

The diagnostic screening of samples to determine glyphosate resistance status is based on survival at 356.4g a.i./ha of a commercial glyphosate formulation. Dose response experiments conducted at our research facility have determined that this dose accurately discriminates between resistant and susceptible populations. From a practical point of view, for the glyphosate product used in the screening, this dose is equivalent to the upper label rate to control sowthistle plants with five or less true leaves (or no more than 3cm in diameter/height), in a fallow situation or prior to planting a crop in the northern region.

In the screening tests, plants are sprayed at the two-to-four leaf stage and herbicide efficacy is assessed 21 days after herbicide treatment (increasing to 35 days in cold weather). Plants are considered survivors if the growing point (centre of the rosette) is green and/or if new leaves are present. A population is deemed "resistant" (R) if ≥20% of the plants survive the glyphosate treatment.

To date a total of 147 sowthistle seed samples have been submitted for glyphosate resistance testing. Of the populations tested, approximately 20% of the populations have shown resistance to glyphosate. For one seed sample, 93% of plants survived glyphosate application at the label rate for small plants. This sample was sourced from survivors of a glyphosate treatment in a fallow situation, located near Gunnedah, NSW.

The good news is that the survey so far indicates many populations remain susceptible to glyphosate, when treated at the small rosette stage and according to label recommendations. Through greater diversity in weed control as part of an integrated approach, it should be possible to retain the effectiveness of this key herbicide for control of common sowthistle.

Samples received to date provide a reasonable geographic coverage of the sampling area (Figure 1). Many samples have been sent in by growers and agronomists in northern NSW and the Southern Downs. However, additional samples are being targeted from central Queensland, the Western Downs, and Maranoa. Growers and agronomists in these areas are particularly encouraged to send in samples – if you can assist, please contact Annie van der Meulen (contact details are provided at the base of this paper).

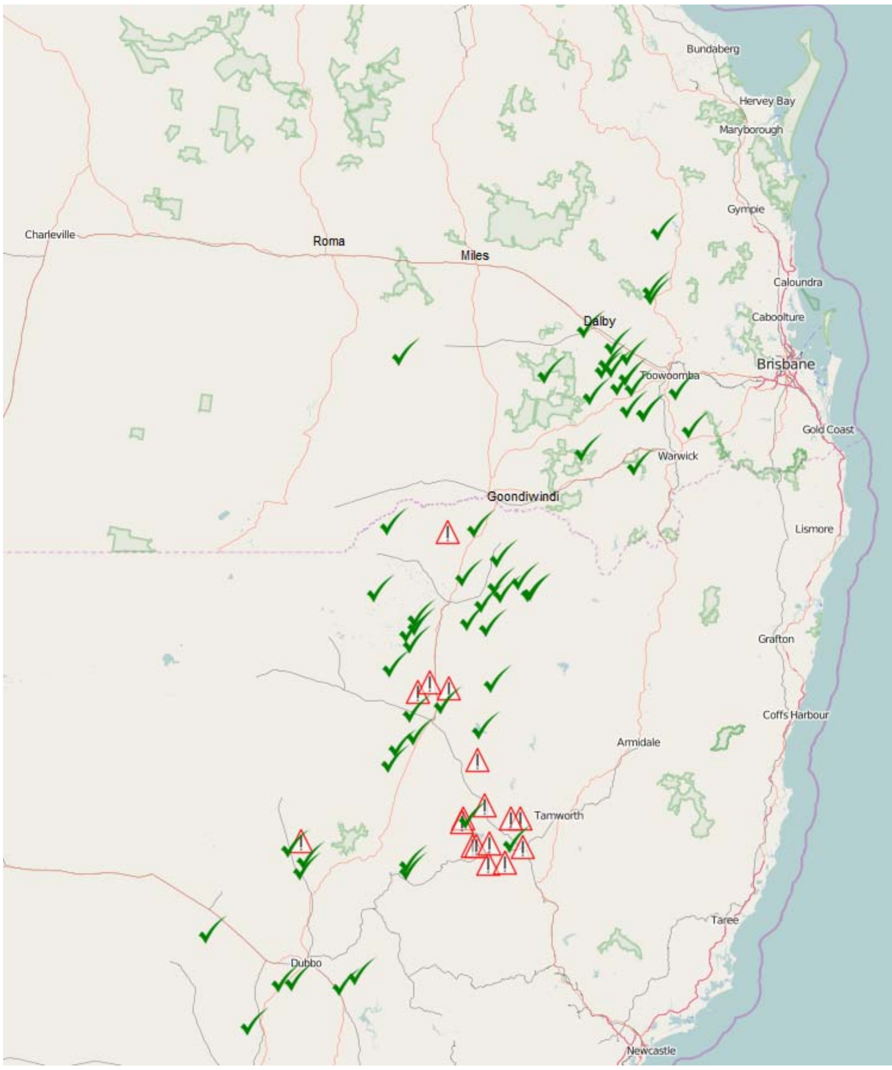

Figure 1: Map showing the location of tested populations. Green tick = susceptible, Red triangle = resistant.

Sowthistle best management

Although glyphosate resistance in common sowthistle is of serious concern, glyphosate remains a viable control option for many populations. Where glyphosate resistance is confirmed, there are other effective options for controlling the weed.

Important control considerations for common sowthistle are as follows:

- It is important to know what herbicides will work. Glyphosate resistance is confirmed to be present in the northern region, and Group B resistance is reported to be widespread.
- Aim for 100% elimination of seed set, including road verges and in channels.
- Maximise crop competition. Grow competitive crop species such as barley at narrow row spacing (e.g. 25cm), and in situations where common sowthistle is a persistent problem, avoid growing poorly competitive crops such as chickpea - this crop has high potential for sowthistle 'blow out.'
- If relying on knockdowns in fallow, treat sowthistle while the plants are small, and double knock to control survivors.
- Apply residuals early in fallow. When using Flame to control summer grasses, remember to partner it with an herbicide effective for controlling common sowthistle.

It is not advisable to rely on spray failure as an indication of herbicide resistance. Not only is spray failure a costly exercise, but there are multiple possible causes including poor application due to adverse environmental conditions and equipment failure. Herbicide resistance testing costs are typically around $125-$150 for a single herbicide, and $75-$95 for each additional herbicide tested. This relatively small expenditure could save considerable financial set-backs in lost production, wasted herbicide, and control costs of driving down a large resistant seed bank.

For specific details on testing options for common sowthistle, contact your local agronomist or a commercial seed testing centre:

Charles Sturt University, Wagga Wagga
Contact: John Broster, 0427 296 641, jbroster@csu.edu.au

Plant Science Consulting, Adelaide
Contact: Peter Boutsalis, 0400 664 460, info@plantscienceconsulting.com.au

Future research

A new GRDC-funded herbicide resistance surveillance project commenced in July 2015 and will involve resistance surveys of key herbicide groups commonly used for northern region weed species common sowthistle, flaxleaf fleabane, awnless barnyard grass and feathertop Rhodes grass. This project is led by Charles Sturt University, in collaboration with Queensland Department of Agriculture and Fisheries, University of Western Australia, and the University of Adelaide. In the northern region, the approach for testing and seed collection is currently being developed.

Acknowledgements

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

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Chickpea on chickpea – is it worth it?

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

Key words

chickpea, Ascochyta, Phytophthora, Sclerotinia, management

GRDC codes

DAN00176, DAN00151

Take home message:

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

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

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

Background

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

What are the risks of back to back chickpea?

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

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

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

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

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

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

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

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

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

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

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

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

There are three:

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

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

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

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

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

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

www.pulseaus.com.au

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

and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

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

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Chickpeas – what we learnt in 2015 and recommendations for 2016

Kevin Moore, Leigh Jenkins, Paul Nash, Gail Chiplin and Sean Bithell, NSW DPI

Key words

chickpea, Ascochyta, Phytophthora, management

GRDC code

DAN00176 Northern NSW Integrated Disease Management

Take home message

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

The 2015 northern NSW/southern QLD chickpea season

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

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

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

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

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

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

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

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

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

Chickpea diseases in 2015

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

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

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

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

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

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

Disease management recommendations for 2016

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

Table 3. Chickpea seed treatments

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

Ascochyta Blight

The following strategy should reduce losses from Ascochyta in 2016:

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

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

Botrytis grey mould, BGM

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

Phytophthora root rot

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

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

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

www.pulseaus.com.au

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

and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

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

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Phytophthora in chickpea varieties HER15 trial –resistance and yield loss

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

Key words

Phytophthora root rot, variety, risk management

GRDC code

DAN00176, DAN00151, DAQ00186, DAS00137

Take home message

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

Varietal resistance to phytophthora root rot

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Acknowledgements

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

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

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Chickpea Ascochyta – latest research on variability and implications for management

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Key words

chickpea, Ascochyta, pathogenicity, latent period

GRDC code

DAN00176, UM00052, DAN00151, DAV00126, DAN00151, DAV00098

Take home message

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

Ascochyta blight in 2015 chickpea crops

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

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

Latest research on variability in the Ascochyta pathogen

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

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

Latent period

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

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

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

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

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

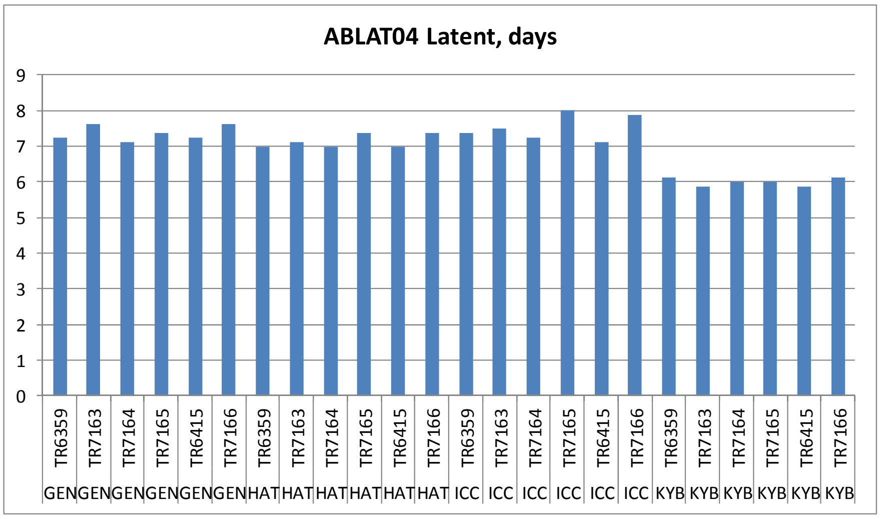

Figure1. Latent period results for experiment ABLAT04 grouped by genotype (ICC3996 (ICC), Genesis 090 (GEN), PBA HatTrick (HAT), Kyabra (KYB)) for inoculation with six isolates listed by isolate no, source and variety: TR6359 2014 North Star NSW, Flipper; TR7165 2014 Horsham VIC; Genesis425, TR7163 2014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

Histopathology experiments

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

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

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

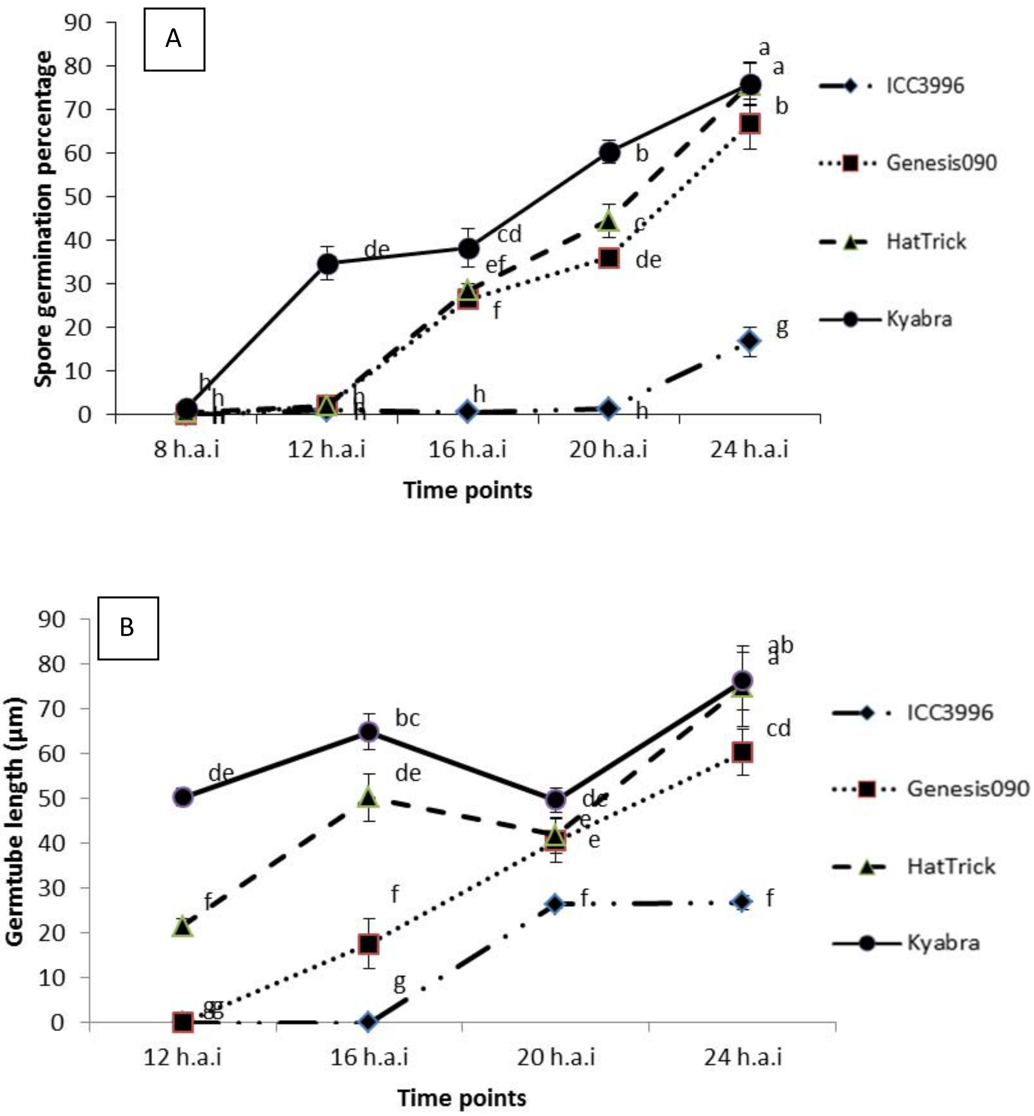

Figure 2. Significant differences were observed among the physiological traits of a highly pathogenic isolate FT13092-1 from Kingsford, SA when inoculated onto chickpea genotypes that are resistant (ICC3996 and Genesis090), moderately resistant (PBA HatTrick) or susceptible (Kyabra). Where A = the percentage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

How is this information used by the PBA Chickpea program?

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

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

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

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

*Advanced breeding lines, putative AB rating

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

Further information

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

www.pulseaus.com.au

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

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

and in the NSW DPI 2016 Winter Crop Variety Sowing Guide

Acknowledgements

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

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

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Key words

Ascochyta, variety, management

GRDC code

DAN00176, DAN00151

Take home message

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

2015 Tamworth Ascochyta management trial, VMP15

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

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

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

Key findings of VMP15 (see Table 2) were:

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

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

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

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

The findings below contrasted between the two VMP experiments

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

Table 1. VMP15 2015 dates, number of rain days (>1 mm rain), mm of rain and dates and number of 1 L/ha chlorothalonil applications, trial sown 18-19 May. VMP Group S (Kyabra⸰), VMP Group MS (PBA Monarch⸰, Genesis Kalkee™, CICA1302, CICA1303), VMP Group MR (PBA HatTrick⸰, PBA Boundary⸰, CICA1007) and R (CICA0912, CICA1007, Genesis 425™). *trial was AB inoculated on 16 June

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

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

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

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

(c) Change in the pathogen; the isolates used in VMP10 were collected from crops in 2008 and 2009 compared to the isolates used in VMP15 which were collected from 1999 to 2014.

Recently collected isolates have shown a higher level of agressiveness on PBA HatTrick. See Ascochyta Variability GRDC Update paper for further information.

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

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

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

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

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

Acknowledgements

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

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