NORTHERN
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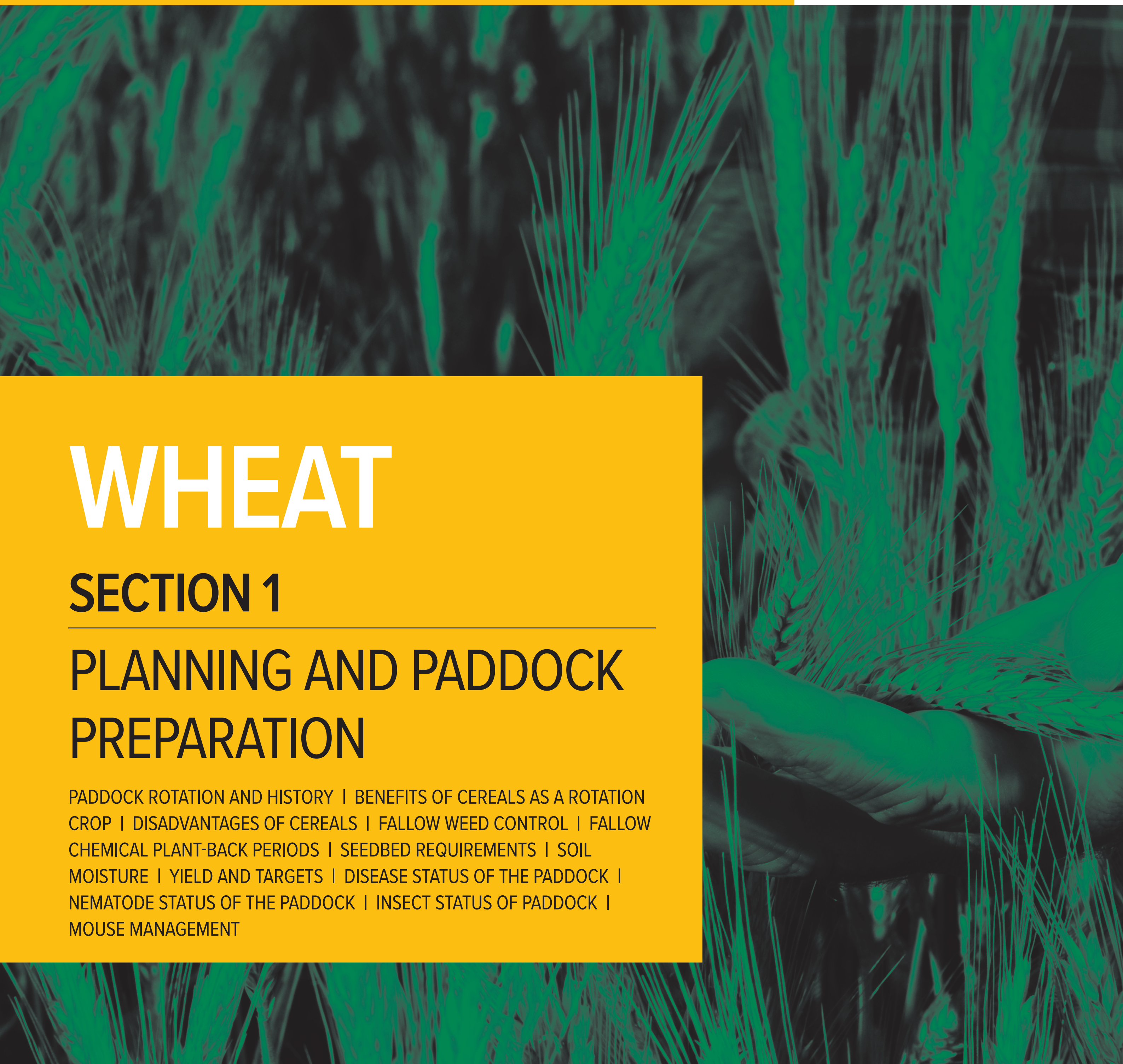
GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION



WHEAT

SECTION 1

PLANNING AND PADDOCK PREPARATION

PADDOCK ROTATION AND HISTORY | BENEFITS OF CEREALS AS A ROTATION CROP | DISADVANTAGES OF CEREALS | FALLOW WEED CONTROL | FALLOW CHEMICAL PLANT-BACK PERIODS | SEEDBED REQUIREMENTS | SOIL MOISTURE | YIELD AND TARGETS | DISEASE STATUS OF THE PADDOCK | NEMATODE STATUS OF THE PADDOCK | INSECT STATUS OF PADDOCK | MOUSE MANAGEMENT

SECTION 1

Planning and paddock preparation

Profitable growing of winter crops demands higher production per unit area while aiming to maintain a low cost per unit of production. This can only be achieved by increasing grain yields through economic adoption of new or improved technology. The aim is not only higher total production, but also greater productivity from the resources invested in crop production, along with total sustainability of the farm business.

Profit depends on choosing the most suitable variety for each paddock and matching this to the paddock's limitations, such as available moisture, diseases and nutrient status. Profitable yields result from good management, of which variety choice is only a minor part.

Paddock selection and rotation combined with use of disease-resistant varieties are the best actions to minimise disease. A table of disease ratings for current varieties can be found in the NSW Department of Primary Industries (DPI) Winter crop variety sowing guide and the Grains Research and Development Corporation (GRDC) Northern Variety Trials (NVT) Queensland Wheat Variety Guide 2013. [1]

More information

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

http://www.grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

Figure 1: Paddock selection and rotation combined with use of disease-resistant varieties are the best actions to minimise disease. (Photo: Penny Heuston)

Paddock selection is an important consideration for crown rot management, in particular, and wheat growers should select paddocks with a low risk of the disease. Paddock risk can be determined by visually assessing crown rot and root-lesion nematode (RLN; see section below) levels in a prior cereal crop, paying attention

[1] NSW DPI District Agronomists (2008) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Management-of-yellow-spot-in-wheat-decide-before-you-sow

More information

https://www.grdc.com.au/~/media/AF642FA0A889465089D2B6C59E5CA22E.pdf

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/520666/Northern-grains-region-trial-results-autumn-2014.pdf

More information

http://www.grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides

http://www.ag.ndsu.edu/cpr/plant-science/impacts-of-flooding-waterlogging-on-crop-development-5-26-11

to basal browning, and/or having soil samples analysed at a testing laboratory. The presence of spores of tan (yellow) spot is also an important consideration, and effective management of this disease in wheat depends on decisions made before sowing.

Paddock history can also provide clues. Histories likely to result in high risk of crown rot include:

- durum wheat in the past 1–3 years
- winter cereal or a high grass burden from last season—crown rot fungus survives in winter cereal residues, dense stubble cover or where dry conditions have made residue decomposition slow
- break crops, which can influence crown rot in cereals by manipulating the amount of nitrogen (N) and moisture left in the soil profile
- paddocks that have high levels of N at sowing and/or low stored soil moisture at depth[2]
- wheat varieties grown in previous years [3]

Paddock topography

Topographical characteristics can determine crop and pasture options. Crops and varieties prone to lodging should be avoided in uneven paddocks. Waterlogged conditions also reduce root growth and can predispose the plant to root rots. [4] Choose varieties with higher tolerance to wet conditions.

Figure 2: Topographical characteristics can determine crop options. (Photo: Penny Heuston)

Soil type

Soil characteristics (surface and subsurface) such as soil pH, sodicity, salinity, acidity, texture, drainage characteristics and compaction will affect variety selection. See the NVT Queensland Wheat Variety Guide 2013 for details of recommended varieties and

[2] GRDC (2009) Crown rot in cereals. GRDC Fact Sheet May 2009, https://www.grdc.com.au/~/media/AF642FA0A889465089D2B6C59E5CA22E.pdf

[3] R Brill, S Simpfendorfer (2013) Resistance of eighteen wheat varieties to the root lesion nematode *Pratylenchus thornei*—Trangie 2011. In: NSW DPI Northern Grains Region Trial Results Autumn 2013, pp. 129–131, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

[4] J Ransom (2011) Impacts of flooding/waterlogging on crop development. North Dakota State University Crop & Pest Report (26 May 2011), http://www.ag.ndsu.edu/cpr/plant-science/impacts-of-flooding-waterlogging-on-crop-development-5-26-11

planting times for individual districts within the northern region. For more detail see Section 2: Preplanting.

Subsoil moisture

Some crops are more expensive than others to grow due to input costs. Low levels of soil moisture at sowing can significantly increase financial risks. Paddocks with ground cover can retain moisture for longer, extending the time for planting after small rainfall events. Levels of starting soil water should also affect variety choice. Varieties with greater canopy size, such as late-maturing and/or very vegetative varieties, will generally require higher soil moisture levels to perform well.

Paddock nutrition

Fertiliser is a major cost. Fertiliser rates to meet crop requirements may be modified if residual fertiliser from the last season remains. Paddock history, past crop performance, fertiliser test strips and soil tests can help to determine the most appropriate decision. It is not uncommon for paddocks to have multiple nutrition deficiencies, or variations in nutritional requirements, even with a similar cropping history.

Herbicide history

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea, triazines etc.) may be an issue in some paddocks. Remember that plant-back periods begin after rainfall occurs. For plant-back periods, see the NSW DPI publication *Weed control in winter crops*.

Weed burden

Identify your 'cleanest' paddocks and consider the use of pre-emergent herbicides. Some broadleaf weed species are difficult and/or expensive to control in pulse and oilseed crops. Risk may be reduced through the combination of pre-sowing weed knockdown, late-sown (early-maturing) crops/varieties and pre-harvest desiccation in crops where registration is current.

Weed management involves strategic herbicide applications in combination with other, non-chemical management options. Weed management in year 1 will affect the crop in year 2. If year 2 is a legume crop, more-vigilant control of broadleaf weeds in year 1's cereal may be a good strategic option.

Disease carryover

Crop sequencing is an important component of long-term farming systems and contributes to the management of soil N status, weeds, pests and diseases. Broadscale decisions on the sequence of crops include commodity prices, the short- and medium-term weather outlook, and the level of acceptable risk.

In the paddock, considerations include soil moisture levels before planting, current and desired stubble cover, history of herbicide use, history of diseases, and the population level(s) of RLN.

The GRDC northern region has seen significant adoption of summer and winter pulses in crop sequences for a variety of reasons, including improved soil N levels and management of crown rot in winter cereals.

For diseases, the focus in the GRDC northern region has been on management of crown rot and RLN, yellow leaf spot in winter cereals, and the roles that rotational crops play, particularly the winter pulses. Crop sequences also affect the incidence and severity of major diseases of summer crops, especially those diseases that have several summer, and in some instances winter, crop hosts. See Table 1: Significant pathogens shared by different crops in the northern region. See Table 2: Susceptibility and resistance of various crops to root-lesion nematodes. [5]

More information

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/weed-control-winter-crops

More information

http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-68-Integrated-Weed-Management-Supplement/Weeds-dont-like-the-competition

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/02/More-crop-less-weeds-Competitive-cereal-cultivars-have-higher-yield-and-suppress-weed-seed-set

Video

To view Paul Castor (MCA Goondiwindi Pty Ltd) highlighting the benefits and potential issues for growing summer crops on narrow rows for greater crop competition with weeds, visit: http://www.grdc.com.au/Media-Centre/GRDC-Gallery/Video/loACpykKja0.

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Diseases-shared-by-different-crops-and-issues-for-crop-sequencing

5 KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

More information

http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

Key outcomes arising from the crop sequence

Crop sequencing is only a part of the integrated management of diseases, other practices include maintaining sufficient distance from last year's paddock of the same crop or from a paddock with residue infected with a pathogen of the intended crop, the use of high-quality, fungicide-treated seed, planting within the planting window, variety selection, and in-crop fungicide treatments. [6]

The previous crop will influence levels of both soil- and residue-borne diseases. Important diseases to consider include take-all, crown rot, yellow leaf spot, stripe rust, and wheat streak mosaic virus. Transmission from neighbouring paddocks and volunteers are key concerns with some diseases. Controlling the 'green bridge' of over-summering cereals and weeds is an important strategy.

Table 1: Significant pathogens shared by different crops in the northern region

Pathogen/ Nematode	Common name	Sorghum	Maize	Sunflower	Summer pulses	Cotton	Winter cereals	Winter pulses
Pratylenchus thornei	root-lesion nematode	-	-	-	✓✓ m,s	-	✓✓	✓✓ c,f
Pratylenchus neglectus	root-lesion nematode	✓✓				nt	✓✓	✓✓ c
Fusarium graminearum	head blight	✓	✓✓	-	-	-	✓✓	-
Macrophomina phaseolina	charcoal rot	✓✓	✓✓	✓✓	✓✓ m,s,g	✓	-	✓
Sclerotinia sclerotiorum, S. minor	sclerotinia rot	-	-	✓✓	✓✓ s,m,g	-	-	✓✓ c,f,p
Sclerotium rolfsii	basal rot	✓	✓	✓	✓✓ s,g	✓	-	-
Fusarium verticillioides	fusarium stalk and cob rot	✓	✓✓	-	-	-	-	-
Fusarium semitectum	fusarium head blight and stalk rot	✓✓	✓	-	-	-	-	-

✓✓ - major disease; ✓ - recorded but generally minor disease; c=chickpeas; f=fababean; g=peanut; m=mungbean; p=field pea; s=soybean; nt=not tested

Pests

Pests such as redlegged earth mites, blue oat mites, nematodes and, in some seasons, cutworms may pose a risk in some paddocks. Risk should be assessed based on paddock history (including recent control) and crop susceptibility. Controlling weeds in summer fallows and around paddocks can also minimise some of these pests. For information on in-furrow treatment options see Section 3: Planting.

More information

https://portal.apvma.gov.au/pubcris

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

For line drawings of soil insects, visit: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects/soil-insects.

For more information, see *Section 3: Planting* and *Section 7: Insect control*.

See also Australian Pesticides and Veterinary Medicines Authority Public Chemical Registration Information System (APVMA PubCRIS database) and NSW DPI Winter crop variety sowing guide websites.

6 M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers 13 September 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/09/Diseases-shared-by-different-crops-and-issues-for-crop-sequencing

Fallow management

Paddocks with well-managed fallow periods significantly lower the risk of poor crop and financial performance.

Timely weed control reduces moisture losses and weed seed set. Maintaining ground cover increases moisture conservation. Absence (or restriction) of grazing periods maintains soil friability and ground cover. Prolonged grazing periods may create crop emergence problems through induced surface compaction. [7] (See *Section 1.5 Fallow weed control.*)

The green bridge provides a 'between-season' host for insects and diseases (particularly rusts); these pose a serious threat to future crops and can be expensive to control later in the season.

Key points for control of the green bridge:

- Outright kill of the weeds and volunteers is the only certain way to avoid them hosting diseases and insects.
- Diseases and insects can quickly spread from the green bridge or summer weeds, jeopardising crops and current control methods, including the effectiveness of chemicals and genetic breeding for resistance.
- Effective control of pest and disease risks requires neighbours to work together to simultaneously eradicate weeds and crop volunteers.
- Weed growth during summer and autumn also depletes soil moisture and nutrients that would otherwise be available to following crops and can have an allelopathic effect. [8]

More information

http://www.grdc.com.au/uploads/documents/GRDC_GreenBridge_FS_6pp.pdf

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/126100/paddock-selection-after-drought.pdf

The GRDC produces an annual Paddock Diary for downloading, which includes information and record-keeping templates.

Diary headings include:

- Your paddocks list
- Paddock operations and paddock observations
- Growth stages
- Pests, diseases and weeds
- Rust risk
- The Australian Cereal Rust Control Program
- Groups (modes of action)
- Herbicide resistance
- How will you spray this year?
- Spray application
- Surface temperature inversions and spraying
- Delta T and droplet survival
- Spray calibration
- Nozzle selection and calculation
- Sprayer checks and calibration
- Pesticide application
- Water-use efficiency (WUE)
- Planting rate
- Rainfall records
- Calendars

7 N Border, K Hertel, P Barker (2007) Paddock selection after drought. NSW Department of Primary Industries February 2007, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/126100/paddock-selection-after-drought.pdf

8 GRDC (2009) Green bridge—the essential crop management tool. GRDC Fact Sheet, http://www.grdc.com.au/uploads/documents/GRDC_GreenBridge_FS_6pp.pdf

More information

http://www.grdc.com.au/paddockdiary

- Public holidays and school terms
- Names and addresses
- Weights and measures
- Conversions formulae
- Useful conversions

1.1 Paddock rotation and history

More information

Dual-purpose wheat and canola - finding the best fit with experiments, experience and modelling

Crop sequencing is a key part of a long-term farming systems approach to tackling weed, disease and moisture challenges in the northern grains region. Nitrogen-fixing summer and winter pulses are gaining popularity as cereal breaks.

Winter cereal–summer crop and winter pulse–summer crop rotations are key strategies for reducing crown rot pressure and the incidence of RLN in the northern region. However, consideration of a crop's potential to host RLN, particularly *Pratylenchus thornei*, should be taken into account (Table 2).

GRDC-supported research aims to increase the profitability of minor rotation crops such as faba beans by improving pest and disease resistance.

Development of new varieties is boosting potential rotation crop yields and disease resistance, and the potential fit of sorghum as part of the rotation in western areas is the subject of further research. [9]

More information

http://www.grdc.com.au/~/media/9219D55FFB4241DC9856D6B4C2D60569.pdf

http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

Table 2: Susceptibility and resistance of various crops to root-lesion nematodes [10]

RLN species	Susceptible	Intermediate	Resistant
Pratylenchus thornei	Wheat, chickpea, faba bean, barley, mungbean, navy bean, soybean, cowpea	Canola, mustard, triticale, durum wheat, maize, sunflower	Canary seed, lablab, linseed, oats, sorghum, millet, cotton, pigeon pea
Pratylenchus neglectus	Wheat, canola, chickpea, mustard, sorghum (grain), sorghum (forage)	Barley, oat, canary seed, durum wheat, maize, navy bean	Linseed, field pea, faba bean, triticale, mungbean, soybean

1.1.1 Sorghum preceding wheat

The benefits are:

- cereal disease break
- control of problem weeds

Risks:

- The opportunity sorghum provides for the build-up of summer grass weeds could present a significant threat for subsequent summer fallows.
- Reduced ground cover of sorghum provides increased erosion risk in the following fallow. The crop choice following the sorghum, including cover crops, can help manage this issue.
- Planting dates for sorghum have been getting progressively earlier in the spring and this is reducing the benefit that the rotation has generally provided for managing wild oats. Wild oats are difficult to manage in sorghum and delayed planting is currently probably the best option.

[9] GRDC (2011) Choosing rotation crops—Short-term profits, long-term payback. GRDC Fact Sheet Northern Region March 2011, http://www.grdc.com.au/~/media/9219D55FFB4241DC9856D6B4C2D60569.pdf

[10] KJ Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

Research presented at the Australian Society of Agronomy Conference in 2012 examined the implications of a wheat–long fallow–sorghum–long fallow–wheat sequence (Verrell 2012). Sorghum is an important summer crop component of the northern NSW farming system. Traditionally, it is grown on a long fallow following wheat, then long-fallowed out to a durum or bread wheat crop. It can provide a break to cereal disease and can control problem weeds.

Row spacing in sorghum varies greatly and increases as potential yield declines. High-yielding sites (>4 t/ha) can have row spacing from as low as 40–60 cm, whereas low yielding sites (<3 t/ha) are generally planted with row configurations >1 m with skip or double-skip rows as options (Serafin and McMullen 2011).

Inter-row sowing has been shown to reduce the impact of crown rot and increase yield in a wheat–wheat sequence, and there was a need to examine whether the effect of row spacing and placement of sorghum and wheat crops would result in differences in grain yield in a 4-year crop sequence.

In this environment (high yield potential), narrow-row sorghum (40 cm) resulted in a higher yield (5.5 t/ha) than wide-row and double-skip configurations (av. 4.7 t/ha), in what could be regarded as an above-average summer-rainfall season in 2009–10.

The biggest influence on the following wheat crop was the row-spacing configuration of the previous sorghum crop. Sowing sorghum in a double-skip arrangement resulted in a 1.0 t/ha yield advantage to the following wheat crop over wide-row sorghum and 1.6 t/ha over a narrow-row configuration. Wheat protein contents >12% suggest that the water-limited potential wheat yield was not inhibited by the amount of available N. However, it was clear that the wheat following the narrow-row sorghum had access to 40 kg less N than wheat following the double-skip sown sorghum.

The worst wheat yield outcome was attributed to a row-placement system that kept sowing over the same row, year after year (4.41 t/ha). The best row placement combination was sowing sorghum over the 2008 wheat rows then sowing the 2011 wheat crop into the inter-row space (4.64 t/ha), meaning that the crop was sown into ground that did not have wheat sown in it for at least 4 years. This inter-row sowing strategy resulted in a 3% wheat yield advantage, on average, over continuous, on-row sowing. This is less than the 9% yield advantage reported by Verrell *et. al*. (2005) in a chickpea–wheat–wheat system, but still supports the finding that inter-row sowing can provide a yield advantage to wheat.

More information

http://www.regional.org.au/au/asa/2012/crop-production/8317_verrellag.htm

Under conditions of high potential sorghum yields, the choice of sorghum row configurations and row placement strategies for both sorghum and the following wheat crop need to be considered in order to maximise yields and limit the impact of crown rot on wheat. [11]

1.1.2 Chickpea preceding wheat

The benefits are:

- improved soil friability
- expanded weed control options
- a break for diseases such as crown rot in wheat
- improved N supply for cereal crops
- improvement in soil health

Risks:

- Poor weed competition: There is potential for build-up of Group A resistant wild oats, as there are few options registered in chickpeas.
- Nematodes: This is a major drawback to planting chickpeas before wheat. Recent field data show consistent differences in *P. thornei* resistance between commercial

11 AG Verrell (2012) Effects of row spacing and row placement on grain yield in a sorghum/wheat sequence under high rainfall. In: Proceedings 16th Australian Agronomy Conference. Australian Society of Agronomy/ The Regional Institute Ltd, http://www.regional.org.au/au/asa/2012/crop-production/8317_verrellag.htm

chickpea varieties. Figure 3 shows a summary of key chickpea variety performance in eight trials sampled by Queensland Department of Agriculture, Fisheries and Forestry (DAFF), NSW DPI or Northern Grower Alliance (NGA).

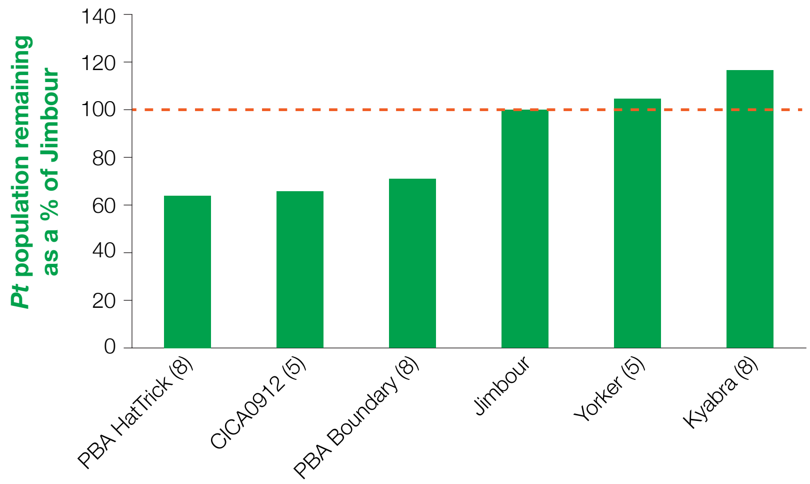


Figure 3: Comparison of Pratylenchus thornei (Pt) population remaining as a percentage of Jimbour 2010–12. Values in parentheses indicate the number of trials compared to Jimbour. The red broken line indicates the Pt level remaining after Jimbour.

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

Chickpea is the preferred broadleaf rotation crop in the predominantly cereal farming systems of the northern region. The crop brings many benefits to the farming system and is currently the most adapted of all rotation crops to the climate, soils and the no-till farming systems of the north.

Chickpea also provides flexibility:

- It is a profitable crop in its own right.
- Crop can be sown in wide rows (up to 100 cm) using a no-till system, which offsets potential for small yield loss.
- Band spraying of wide rows reduces the amount of pesticide in the environment.
- Ability to deep sow provides the opportunity to plant on time most years.

More information

http://www.grdc.com.au/GRDC-Booklet-ManagingFertiliserN

http://www.pulseaus.com.au/pdf/Northern%20Grain%20Production%20-%20a%20farming%20systems%20approach.pdf

Depending on the scale of the farm operation, other winter rotation crops and summer crops could be integrated into a rotation that contains chickpea. Several long-term rotation trials have quantified the benefits of chickpea to following cereal crops and to the overall farming system. There will always be variances between soil types, rainfall patterns and a range of other factors that all influence the final yield outcome. In most situations, chickpea can increase soil N by up to 35 kg nitrate-N/ha and yields of following wheat crops by up to 1 t/ha, with an additional 1% of protein (Table 3). [12]

Legumes must be well nodulated for maximum N fixation and soil N benefits. In most situations, growers will need to inoculate at sowing to ensure good levels of nodulation. If nodulation is adequate, legume N fixation is strongly and positively linked to productivity, and is suppressed by soil nitrate. Higher yields of legume crops also mean higher N and greater yield benefits for the following cereal crop. [13]

12 M Lucy, D McCaffery, J Slatter (2006) Northern grain production—a farming systems approach. 2nd edn. Pulse Australia Ltd, http://www.pulseaus.com.au/pdf/Northern%20Grain%20Production%20-%20a%20farming%20systems%20approach.pdf

13 D Herridge (2013) Managing legume and fertiliser N for northern grains cropping. Revised version. GRDC 31 May 2013, http://www.grdc.com.au/GRDC-Booklet-ManagingFertiliserN

Table 3: Summary of a decade of experimental results from the northern grains belt showing the rotational benefits of chickpea on yield and grain protein levels of the following wheat crop, with and without fertiliser nitrogen (N)

Sites/rotations	Nil fertiliser N		Fertiliser N (75–150 kg N/ha)	
	Yield (t/ha)	Protein (%)	Yield (t/ha)	Protein (%)
New South Wales				
Chickpeas	1.9		1.9	
Wheat after wheat	2.1	11.2	2.7	13.2
Wheat after chickpeas	2.8	12.2	2.9	13.8
Queensland				
Chickpeas	1.5			
Wheat after wheat	2.2	10.3	2.8	13.8
Wheat after chickpeas	2.8	11.7	3.1	13.8

Source: Lucy *et al.* 2005.

1.1.3 Long fallow disorder

Soils naturally contain beneficial fungi that help the crop to access nutrients such as phosphorus (P) and zinc (Zn). The combination of the fungus and crop root is known as arbuscular mycorrhiza(e) (AM). Many different species of fungi can have this association with the roots of crops. Many that are associated with crops also form structures called vesicles in the roots.

The severe reduction or lack of AM shows up as long fallow disorder—the failure of crops to thrive despite adequate moisture. Ongoing drought in the 1990s and beyond has highlighted long fallow disorder where AM have died out through lack of host plant roots during long fallow periods. As cropping programs restart after dry years, an unexpected yield drop is likely due to reduce AM levels, making it difficult for the crop to access nutrients.

Long fallow disorder is usually typified by poor crop growth. Plants seem to remain in their seedling stages for weeks and development is very slow.

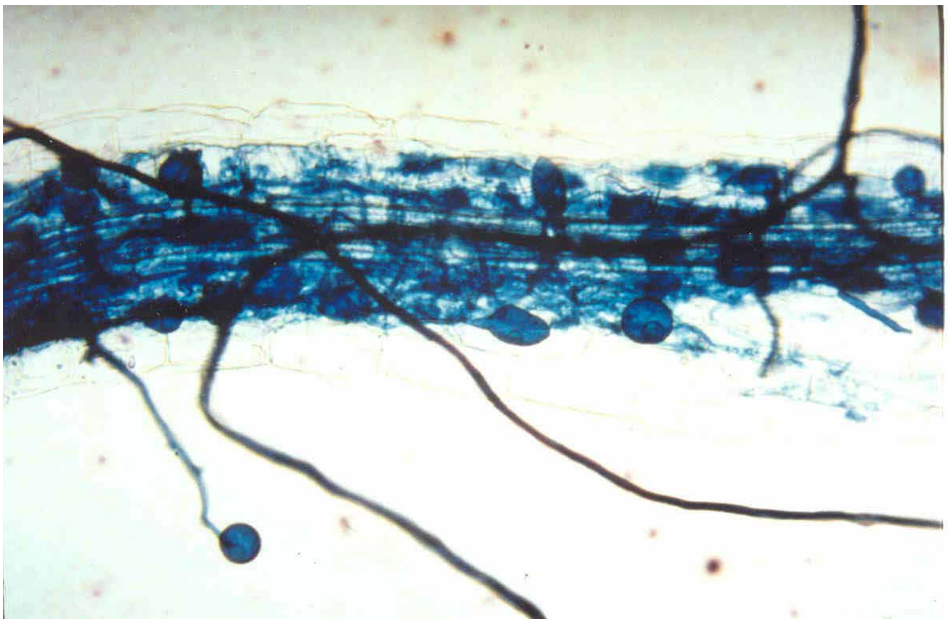


Figure 4: AM pictured in a wheat root. (Photo: QDAFF)

Benefits of good AM levels are:

- improved uptake of P and Zn
- improved crop growth
- improved N_2 fixation
- greater drought tolerance
- improved soil structure
- greater disease tolerance

In general, the benefits of AM are greater at lower soil P levels because AM increase a plant's ability to access this nutrient. Crops with higher dependency benefit more from AM (Table 4). [14]

Table 4: Dependency of various crop species on mycorrhizae (value decreases as the phosphorus level of the soil increases)

Mycorrhiza dependency	Potential yield loss without mycorrhiza (%)	Crops
Very high	>90	Linseed
High	60–80	Sunflower, mungbean, pigeon pea, maize, chickpea
Medium	40–60	Sudan grass, sorghum, soybean
Low	10–30	Wheat, barley, triticale
Very low	0–10	Panicum, canary grass
Nil	0	Canola, lupins

More information

http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/nutrition-vam

1.2 Benefits of cereals as a rotation crop

Cereals present the opportunity for effective utilisation of residual N. They also offer good options for broadleaf control and are non-hosts for many pulse crop and oilseed diseases. A major benefit of winter cereal crops is the high levels of groundcover they provide for management of soil loss in following fallows, as well more reliable planting prospects in subsequent crops.

1.3 Disadvantages of cereals

Growing cereals in continuous production is no longer a common practice in the northern grains region due to the rising incidence of:

- difficult-to-control and herbicide-resistant weeds, particularly grass weeds
- disease build-up, e.g. crown rot, tan (yellow) spot, nematodes
- nitrogen depletion and declining soil fertility

Crop rotation is a key strategy for managing northern farming systems, and improvements in legume and oilseed varieties and management have facilitated this shift.

In many of Australia's grain-growing regions, broadleaf crop options have been seen as riskier and less profitable than cereals. This perception has been driven, in part, by fluctuating prices and input costs associated with the broadleaf crop in the year of production, and difficulties in marketing. However, when the profitability of the entire rotation is assessed, it is more profitable to include broadleaf crops in the crop sequence.

[14] DAFF (2010) Nutrition—VAM and long fallow disorder. Department of Agriculture, Fisheries and Forestry Queensland, 14 Sept. 2010, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/nutrition-vam

A broadleaf crop is often included in the crop sequence to counteract limitations in the cereal phase (weeds, disease, N), so the broadleaf crop's financial impact could be considerably better if considered across the crop sequence. [15]

Leading growers and advisers advocate sustainable rotations as a valuable strategy for northern farming systems. In a survey of leading growers, it was reported that those adopting farming systems based on best management practices allocated about 25% of their winter cropping area to chickpeas or other broadleaf crops.

Their major motivation for introducing a non-cereal was to break the crown rot cycle and consequently improve profitability. The growers reported in the survey that subsequent wheat crops, following a rotation crop, averaged up to 1 t/ha extra yield as well as an additional 1% grain protein. In addition, the growers reported savings in N and weed control inputs.

Many growers are sacrificing cereal yield and protein by not adopting current research findings on the use of rotations. [16]

Modern conservation cropping systems increasingly involve successive wheat, no-till crops which can suffer 5–15% yield penalties from unidentified biological constraints in the rhizosphere. Evidence from field and laboratory studies show that some wheat varieties perform better in these conditions, due to differences in the chemistry of root exudates/residues, which influence rhizobacterial populations. Varietal differences also interact with soil type, season and agronomic management (sowing time, row placement).

CSIRO researchers have developed hypotheses that may explain these effects and aim to establish which selected wheat varieties perform better in intensive wheat rotations, and to improve industry understanding of the mechanisms involved. These steps are necessary to capitalise on the significant increase in productivity for the grains industry that would arise from breeding and/or agronomic strategies to overcome the productivity constraints in intensive cereal systems. [17]

More information

http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-98-Supplement-Crop-Sequencing/Returns-from-break-crops-can-challenge-wheat

http://www.grdc.com.au/~/media/9219D55FFB4241DC9856D6B4C2D60569.pd

http://www.grdc.com.au/Research-and-Development/Meeting-market-requirements/CSP00115

1.4 Fallow weed control

Paddocks generally have multiple weed species present at the same time, making weed control decisions more difficult and often involving a compromise after assessment of the prevalence of key weed species. Knowing your paddock and controlling weeds as early as possible are important for good control of fallow weeds. Information is included for the most common problem weeds; however, for advice on individual paddocks you should contact your agronomist.

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer before in a long fallow) is integral to winter cropping in the northern region, particularly so as the climate moves towards summer-dominant rainfall.
- Modelling studies show that the highest return on investment in summer weed control is for lighter soils or in situations where soil water that would support continued weed growth is present. [18]

More information

http://www.grdc.com.au/Resources/Factsheets/2012/09/Summer-Fallow-Spraying-Factsheet

Summer weeds reduce moisture and nitrogen

15 M Peoples (2012) Returns from break crops can challenge wheat. GRDC Ground Cover Issue 98, 27 April 2012, http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-98-Supplement-Crop-Sequencing/Returns-from-break-crops-can-challenge-wheat

16 GRDC (2011) Choosing rotation crops—Short-term profits, long-term payback. GRDC Fact Sheet Northern Region March 2011, http://www.grdc.com.au/~/media/9219D55FFB4241DC9856D6B4C2D60569.pdf

17 J Kirkegaard Improving productivity by rotating wheat varieties in wheat on wheat systems. GRDC Research & Development Project CSP00115, http://www.grdc.com.au/Research-and-Development/Meeting-market-requirements/CSP00115

18 GRDC (2012) Summer fallow—make summer weed control a priority. GRDC Fact Sheet January 2012.

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

The NGA is trialing methods to control summer grasses. Key findings include:

1. Glyphosate resistant and tolerant weeds are a major threat to our reduced tillage cropping systems.
2. Although residual herbicides will limit recropping options and will not provide complete control, they are a key part of successful fallow management.
3. Double-knock herbicide strategies (sequential application of two different weed control tactics) are useful tools but the herbicide choices and optimal timings will vary with weed species.
4. Other weed management tactics can be incorporated, e.g. crop competition, to assist herbicide control.
5. Cultivation may need to be considered as a salvage option to avoid seed bank salvage.

Double-knock strategies

Double-knock refers to the sequential application of two different weed-control tactics applied in such a way that the second tactic controls any survivors of the first. Most commonly used for pre-sowing weed control, this concept can also be applied in-crop.[19]

More information

http://www.agric.wa.gov.au/objtwr/imported_assets/content/pw/weed/iwm/tactic%20 2.2doubleknock.pdf

Consider the species present, interval timing and water rate. For information on double-knock tactics, download the GRDC Herbicide Application Fact Sheet - Effective Double Knock Herbicide Applications Northern Region from: http://www.grdc.com.au/Resources/Factsheets/2012/09/Herbicide-Application-fact-sheet-Effective-Double-Knock-Herbicide-Applications-Northern-Region.

Double-knock herbicide strategies are useful tools for managing difficult-to-control weeds but there is no 'one size fits all' treatment.

The interval between double-knock applications is a major management issue for growers and contractors. Shorter intervals can be consistently used for weeds where herbicides appear to be translocated rapidly (e.g. awnless barnyard grass, ABYG) or when growing conditions are very favourable. Longer intervals are needed for weeds where translocation appears slower (e.g. fleabane, feathertop Rhodes grass and windmill grass).

Critical factors for successful double-knock approaches are for the first application to be on small weeds and to ensure good coverage and adequate water volumes particularly when using products containing paraquat. Double-knock strategies are not fail-proof and rarely effective for salvage weed-control situations unless environmental conditions are exceptionally favourable.

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Weeds-and-resistance-considerations-for-awnless-barnyard-grass-Chloris-spp-and-fleabane-management

Important weeds in northern cropping systems

Weed management, particularly in reduced tillage fallows, has become an increasingly complex and expensive part of cropping in the northern grains region. Heavy reliance on glyphosate has selected for species that were naturally more glyphosate tolerant or has selected for glyphosate-resistant populations. The four key weeds that are causing major cropping issues are:

1. ABYG (*Echinochloa colona*)
2. Flaxleaf fleabane (*Conyza bonariensis*)
3. Feathertop Rhodes grass (FTR) (*Chloris virgata*)
4. Windmill grass (*Chloris truncata*)

[19] C Borger, V Stewart, A Storrie. Double knockdown or 'double knock'. Department of Agriculture and Food Western Australia, http://www.agric.wa.gov.au/objtwr/imported_assets/content/pw/weed/iwm/tactic%20 2.2doubleknock.pdf

Awnless barnyard grass

Figure 5: Awnless barnyard grass. (Photo: Rachel Bowman)

This has been a key summer grass problem for many years. It is a difficult weed to manage for at least three main reasons:

1. Multiple emergence flushes (cohorts) each season
2. Easily moisture-stressed, leading to inconsistent knockdown control
3. Glyphosate-resistant populations increasingly being found

Key points

- Glyphosate resistance is widespread. Tactics against this weed must change from glyphosate alone.
- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- Try to ensure that a double-knock of glyphosate followed by paraquat is used on one of the larger early summer flushes of ABYG.
- Restrict Group A herbicides to management of ABYG in-crop and aim for strong crop competition.

Resistance levels

Prior to summer 2011–12, there were 21 cases of glyphosate-resistant ABYG. Collaborative surveys were conducted by NSW DPI, DAFF and NGA in summer 2011–12 with a targeted follow-up in 2012–13. Agronomists from the Liverpool Plains to the Darling Downs and west to areas including Mungindi collected ABYG samples, which were tested at the Tamworth Agricultural Institute with Glyphosate CT at 1.6 L/ha (a.i. 450 g/L) at a mid-tillering growth stage. Total application volume was 100 L/ha.

The main finding from this survey work was that the number of 'confirmed' glyphosate-resistant ABYG populations had nearly trebled. Selected populations were also evaluated in a separate glyphosate rate-response trial. The experiment showed that some of these populations were suppressed only when sprayed with 12.8 L/ha.

Growers can no longer rely on glyphosate alone for ABYG control.

Residual herbicides (fallow and in-crop)

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

Double-knock control

This approach uses two different tactics applied sequentially. In reduced tillage situations, it is frequently glyphosate first followed by a paraquat-based spray as the second application or 'knock'. Trials to date have shown that glyphosate followed by paraquat has given effective control even on glyphosate-resistant ABYG. Note that most effective results will be achieved from paraquat-based sprays by using higher total application volumes (100 L/ha) and by targeting seedling weeds.

Several Group A herbicides, e.g. Verdict® and Select®, are effective on ABYG but should be used in registered summer crops, e.g. mungbeans. Even on glyphosate-resistant ABYG, a glyphosate followed by paraquat double-knock is an effective tool. In the same situations there has been little benefit from a Group A followed by paraquat application. Note that Group A herbicides appear more sensitive to ABYG moisture stress. Application on larger, mature weeds can result in very poor efficacy.

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

Flaxleaf fleabane

Figure 6: Flaxleaf fleabane. (Photo: QDAFF)

There are three main species of fleabane in Australia: *Conyza bonariensis* (flaxleaf fleabane), *C. canadensis* (Canadian fleabane) and *C. albida* (tall fleabane). There are two varieties of *C. canadensis*: var. *canadensis* and var. *pusilla*. Of the three species, flaxleaf fleabane is the most common across Australia. [20]

For more than a decade, flaxleaf fleabane (*C. bonariensis*) has been the major weed management issue in the northern cropping region, particularly in reduced tillage systems. Fleabane is a wind-borne, surface-germinating weed that thrives in situations of low competition. Germination flushes typically occur in autumn and spring when surface soil moisture levels stay high for a few days. However, emergence can occur at nearly all times of the year.

An important issue with fleabane is that knock-down control of large plants in the summer fallow is variable and can be expensive due to reduced control rates.

Key points

- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- This weed thrives in situations of low competition; avoid wide row cropping unless effective residual herbicides are included.
- 2,4-D is a crucial tool for consistent double-knock control.
- Successful growers have increased their focus on fleabane management in winter (crop or fallow) to avoid expensive and variable salvage control in the summer.

More information

http://www.glyphosateresistance.org.au/register_summary.html

http://www.agric.wa.gov.au/objtwr/imported_assets/content/pw/weed/major/fleabane.pdf

Resistance levels

Glyphosate resistance has been confirmed in fleabane. There is great variability in the response of fleabane to glyphosate with many samples from non-cropping areas still well controlled by glyphosate, whereas fleabane from reduced tillage cropping situations shows increased levels of resistance. The most recent survey has focused on non-cropping situations, with a large number of resistant populations found on roadsides and railway lines where glyphosate alone has been the principal weed management tool employed.

Residual herbicides (fallow and in-crop)

One of the most effective strategies to manage fleabane is the use of residual herbicides during fallow or in-crop. Trials have consistently shown good efficacy from a range of residual herbicides commonly used in sorghum, cotton, chickpea and winter cereals. There are now at least two registrations for residual fleabane management in fallow.

Additional product registrations for in-crop knockdown and residual herbicide use, particularly in winter cereals, are still being sought. A range of commonly used winter cereal herbicides exists with useful knockdown and residual fleabane activity. Trials to date have indicated that increasing water volumes from 50 to 100 L/ha may help the consistency of residual control, with application timing to ensure good herbicide/soil contact also important.

Knockdown herbicides (fallow and in-crop)a

Group I herbicides have been the major products for fallow management of fleabane, with 2,4-D amine the most consistent herbicide evaluated. Despite glyphosate alone generally giving poor control of fleabane, trials have consistently shown a benefit from tank mixing 2,4-D amine and glyphosate in the first application. Amicide® Advance at 0.65–1.1 L/ha mixed with Roundup® Attack at a minimum of 1.15 L/ha and then followed by Nuquat® at 1.6–2.0 L/ha is a registered option for fleabane knockdown in fallow. Sharpen is a product with Group G mode of action. It is registered for fallow control when mixed with Roundup Attack at a minimum of 1.15 L/ha but only on fleabane up to a maximum of six leaves. Currently, the only in-crop knockdown registration is for Amicide Advance at 1.4 L/ha in either wheat or barley.

For more information on label rates, visit: www.apvma.gov.au

[20] M Widderick, H Wu. Fleabane. Department of Agriculture and Food Western Australia, http://www.agric.wa.gov.au/objtwr/imported_assets/content/pw/weed/major/fleabane.pdf

Double-knock control

The most consistent and effective double-knock control of fleabane has included 2,4-D in the first application followed by paraquat as the second. Glyphosate alone followed by paraquat will result in high levels of leaf desiccation but plants will nearly always recover.

Timing of the second application in fleabane is generally aimed at ~7–14 days after the first application. However, the interval to the second knock appears quite flexible. Increased efficacy is obtained when fleabane is actively growing or if rosette stages can be targeted. Although complete control can be obtained in some situations, e.g. summer 2012–13, control levels will frequently reach only ~70–80%, particularly when targeting large, flowering fleabane under moisture-stressed conditions. The high cost of fallow double-knock approaches and inconsistency in control level of large, mature plants are good reasons to focus on proactive fleabane management at other growth stages.

More information

http://www.qaafi.uq.edu.au/content/Documents/weeds/IWM-Fleabane-guide.pdf

Feathertop Rhodes grass

Figure 7: Feathertop Rhodes grass. (Photo: Rachel Bowman)

Feathertop Rhodes grass has emerged as an important weed management issue in southern Queensland and northern NSW since ~2008. This is another small-seeded weed species that germinates on, or close to, the soil surface. It has rapid early growth rates and can become moisture stressed quickly. Although FTR is well established in central Queensland, it remains largely an 'emerging' threat further south. Patches should be aggressively treated to avoid whole-of-paddock blow-outs.

Key points

- Glyphosate alone or glyphosate followed by paraquat has generally poor efficacy.
- Utilise residual chemistry wherever possible and aim to control 'escapes' with camera spray technology.
- A double-knock of Verdict followed by paraquat can be used in Queensland prior to planting mungbeans where large spring flushes of FTR occur.
- Treat patches aggressively, even with cultivation, to avoid paddock blow-outs.

Residual herbicides (fallow and in-crop)

This weed is generally poorly controlled by glyphosate alone even when sprayed under favourable conditions at the seedling stage. Trials have shown that residual herbicides generally provide the most effective control, a similar pattern to that seen with fleabane. Currently registered residual herbicides are being screened and offer promise in both fallow and in-crop situations. The only product currently registered for FTR control is Balance (isoxaflutole) at 100 g/ha for fallow use.

Double-knock control

A glyphosate followed by paraquat double-knock is an effective strategy on ABYG; however, the same approach is variable and generally disappointing for FTR management. By contrast, a small number of Group A herbicides (all members of the 'fop' class) can be effective against FTR but need to be managed within a number of constraints:

- Although they can provide high levels of efficacy on fresh and seedling FTR, they need to be followed by a paraquat double-knock to get consistent high levels of final control.
- Group A herbicides have a high risk of resistance selection, again requiring follow-up with paraquat.
- Many Group A herbicides have plant-back restrictions to cereal crops.
- Group A herbicides generally have a narrower range of weed growth stages for successful use than herbicides such as glyphosate, i.e. Group A herbicides will generally give unsatisfactory results on flowering and/or moisture-stressed FTR.
- Not all Group A herbicides are effective on FTR.

For information on a permit (PER12941) issued for Queensland only for the control of FTR in summer fallow situations prior to planting mungbeans, see www.apvma.gov.au

Timing of the second application for FTR is still being refined, but application at ~7–14 days generally provides the most consistent control. Application of paraquat at shorter intervals can be successful, when the Group A herbicide is translocated rapidly through the plant, but has resulted in more variable control in field trials. Good control can often be obtained up to 21 days after the initial application.

More information

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Windmill-grass-Chloris-truncata-the-current-state-of-play

Windmill grass

Figure 8: Windmill grass. (Photo: Maurie Street)

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

Key points

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

Resistance levels

Glyphosate resistance has been confirmed in windmill grass with three documented cases in NSW, all located west of Dubbo. Glyphosate-resistant populations of windmill grass in other states have all been collected from roadsides, but in central west NSW, two were from fallow paddock situations.

Residual herbicides (fallow and in-crop)

Preliminary trials have shown a range of residual herbicides with useful levels of efficacy against windmill grass. These herbicides have potential for both fallow and in-crop situations. Currently, there are no products registered for residual control of windmill grass.

Double-knock control

Similar to FTR, a double-knock of a Group A herbicide followed by paraquat has provided clear benefits compared with the disappointing results usually achieved by glyphosate followed by paraquat. Constraints apply to double-knock for windmill grass control similar to those for FTR.

For information on a permit for NSW only for the control of windmill grass in summer fallow situations, visit www.apvma.gov.au

Timing of the second application for windmill grass is still being refined, but application at ~7–14 days generally provides the most consistent control. Application of paraquat at shorter intervals can be successful, when the Group A herbicide is translocated rapidly through the plant, but has resulted in more variable control in field trials and has been clearly antagonistic when the interval is one day or less. Good control can often be obtained up to 21 days after the initial application. [21]

More information

http://www.grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS102/Herbicide-resistance-in-summer-grasses

http://www.nga.org.au/module/documents/download/225

1.5 Fallow chemical plant-back periods

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop.

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas (chlorsulfuron)). This is shown in the Table 5 where known. Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the 'Protection of crops etc.' heading in the 'General Instructions' section of the label. [22]

[21] R Daniel (2013) Weeds and resistance—considerations for awnless barnyard grass, *Chloris* spp. and fleabane management. Northern Grower Alliance, http://www.nga.org.au/module/documents/download/225

[22] B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

Table 5: Residual persistence of common pre-emergent herbicides, and noted residual persistence in broad acre trials and paddock experiences [23]

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within 6 weeks
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than Logran
Diuron	90 (range 1 month to 1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Has had observed long-lasting activity on grass weeds such as black/stink grass (*Eragrostis* spp.) and to a lesser extent broadleaf weeds such as fleabane
Atrazine	60–100, up to 1 year if dry	High. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane
Simazine	60 (range 28–149)	Med./high. 1 year residual in high pH soils. Has had observed long lasting (>3 months) activity on broadleaf weeds such as fleabane
Terbyne® (terbulthylazine)	6.5–139	High. Has had observed long lasting (>6 months) activity on broadleaf weeds such as fleabane and sow thistle
Triflur® X (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Has had observed long lasting activity on grass weeds such as black/stink grass (*Eragrostis* spp.)
Stomp® (pendimethalin)	40	Medium. 3–4 months residual
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months residual
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed long lasting (> 6 months) activity on broadleaf weeds such as fleabane and sow thistle
Boxer Gold® (prosulfocarb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall event
Sakura® (pyroxasulfone)	10–35	High. Typically quicker breakdown than Trifluralin and Boxer Gold;, however, weed control persists longer than Boxer Gold

Sources: CDS Tomlinson (ed,) (2009) The pesticide manual. 15th edn. British Crop Protection Council, Farnham, UK. Extoxnet: http://extoxnet.orst.edu/. California Dept Pesticide Regulation Environmental Fate Reviews, www.cdpr.ca.gov/

More information

www.apvma.gov.au

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

Download

Download the NSW DPI publication, Weed Control in Winter Crops at http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/weed-control-winter-crops

[23] B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

More information

http://www.basf.com.au

1.5.1 Genetic controls

The Clearfield® Production System is designed to deliver extended weed control and increased yield potential and crop quality. [24] It matches selected seed varieties with Intervix®, a custom-designed herbicide that can only be used on Clearfield® varieties. Refer to the herbicide label for weed species that can be controlled.

The varieties are not genetically modified organisms (GMO) and include AGT Elmore CL Plus wheat suited to the northern region.

1.6 Seedbed requirements

Wheat seed needs good soil contact for germination. This can be assisted with press wheels, coil packers or rollers. Soil type determines the implement that produces the ideal seedbed.

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

Between 70 and 90% of seeds sown produce a plant if vigour and germination are high. Depth of sowing, disease, crusting, moisture and other stress in the seedbed all reduce the number of plants establishing. Field establishment is unlikely to be more than 90% and may be as low as 60% if seedbed conditions are unfavourable.

Seedbed preparation is also important to emergence. A cloddy seedbed may reduce emergence, as the clods allow light to penetrate below the soil surface. The coleoptile senses the light and stops growing while still below the surface. [25]

1.6.1 Deep sowing

For successful crop establishment, seed needs to be placed into soil with enough seedbed moisture for germination to occur, or into dry soil with the anticipation of rainfall to increase soil moisture levels such that germination may occur. In north-western NSW it is common for soil profiles to have high levels of plant-available water in the root-zone, coupled with a dry seedbed. This scenario may require implementation of the practice of 'moisture seeking', where seed is placed deeper in the soil than is generally recommended, with the main aim of ensuring timely crop establishment. This practice generally involves the use of tines to open a furrow to a depth of >7.5 cm, into which the seed is then placed, followed by a press wheel to close moist soil around the seed. Cox and Chapman (2007) reported that 'moisture seeking' increases cropping frequency and improves timeliness of crop establishment.

1.6.2 Coleoptile length

Most wheat varieties currently grown in Australia contain a reduced-height gene that results in shorter plants and shorter coleoptiles than standard-height varieties (Gooding *et al.* 2006). Whan (1976*b*) reported a positive correlation between coleoptile length and crop establishment, which implies that widely grown, semi-dwarf varieties have reduced establishment compared with standard-height varieties when sown deep.

[24] Crop Care (2011) Clearfield best management practice. Crop Care Australasia Pty Ltd, http://www.basf.com.au

[25] District Agronomists (2008) Wheat growth and development. PROCRP Series, NSW Department of Primary Industries 2007, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

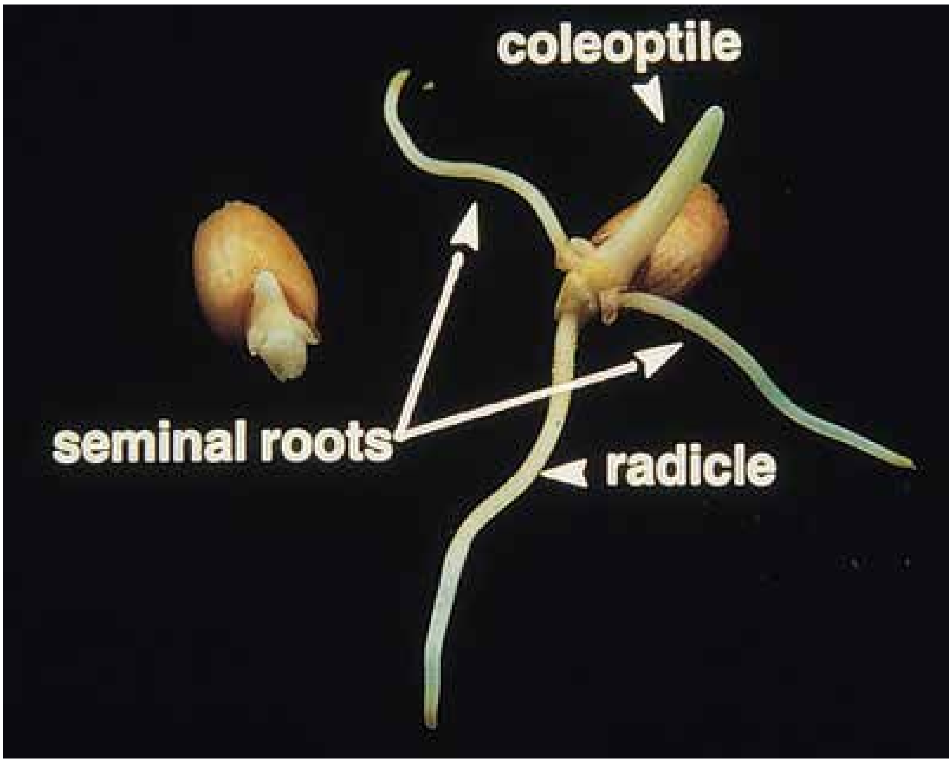


Figure 9: Germinated wheat seed. (Photo: University of Minnesota, David L. Hansen)

There have been regular claims across the grains industry in north-western NSW that the milling wheat variety EGA Gregory established poorly from deep sowing relative to other varieties. Hence, trials were conducted over three seasons (2009–11) in the Coonamble region to evaluate differences between commonly grown commercial bread wheat and durum varieties in their ability to establish from deep sowing. In addition, the effect of the fungicide triadimenol on wheat establishment was determined in 2009 and 2010. In 2011 a sowing time factor was also examined, to determine the link between the level of establishment achieved and the timing of crop establishment.

More information

http://www.dpi.nsw.gov.au/agriculture/broadacre/winter-crops/winter-cereals/coleoptile-length

1.6.3 Moisture seeking

The trials from 2009 to 2011 showed that deep sowing could significantly affect the establishment and yield of wheat; however, none of the varieties evaluated showed an enhanced ability to establish from deep sowing compared with other commonly grown varieties in north-western NSW. There are several decisions producers need to make when considering moisture seeking; however, there appears no advantage in crop establishment from changing varieties.

It was unclear from the trials whether the reduced yield from deep sowing was due to a reduced plant population or due to subsequent effects on crop growth and development. McMullen *et al.* (2011) reported that, for trials sown at the same site and season as the 2009 sowing-depth trial, there was no significant difference in wheat yield for plant populations in the range 60–180 plants/m^2. However, the lower plant populations in that work were still higher than the populations achieved in the deep-sowing treatments of the sowing depth trials. Fischer *et al.* (2005) reported that maximum yield could be achieved by plant populations as low as 24 plants/m^2, provided the plants were arranged in a perfect matrix. This was not the case for the trials reported in this paper; hence, some yield effect was likely due to reduced population. Herbek *et al.* (2005) reported that deep sowing reduces tillering and subsequent head number per plant and per unit area, which may also have reduced yield in these trials.

The 2011 trial highlighted the potential benefits of moisture seeking; in that season, reduced establishment from a relatively early sowing that was sown deep resulted

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

More information

http://www.regional.org.au/au/asa/2012/crop-production/8196_brillr.htm#TopOfPage

in higher yield than a shallow, late sowing that achieved a higher plant population. In this trial, the effect of delayed sowing on wheat yield was greater than the effect of deep sowing on wheat yield. Doyle and Marcellos (1973) reported on a trial in northern NSW where there was a 9–13.5% yield loss of wheat for each week that flowering was delayed beyond the optimal time for a particular region. Where producers and agronomists are faced with situations of low seedbed moisture but high plant-available water beyond the seedbed (>5 cm soil depth), planting decisions need to balance the potential effect of reduced yield from deep sowing with the potential yield loss from delayed sowing. [26]

1.7 Soil moisture

1.7.1 Dryland

Water availability is a key limiting factor for wheat production in the northern grain belt of Australia. Varieties with improved adaptation to such conditions are actively sought and studies have been carried out to identify the physiological basis of the adaptive traits underpinning this advantage. Experiments were undertaken in field environments that represented the range of moisture availability conditions commonly encountered by winter crops grown on the deep Vertosol soils of this region.

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

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

The yield of SeriM82 was 6–28% higher than that of Hartog, and SeriM82 exhibited a stay-green phenotype by maintaining green leaf area longer during the grain-filling period in all environments where yield was significantly higher than that of Hartog. However, where the availability of deep soil moisture was limited, SeriM82 failed to show significantly higher yield or to express the stay-green phenotype. Thus, the stay-green phenotype was closely associated with the yield advantage of SeriM82. SeriM82 also exhibited higher mean grain mass than Hartog in all environments.

Small differences in water use before anthesis, or greater water extraction from depth after anthesis, could underlie the stay-green phenotype. The inability of SeriM82 to exhibit stay-green and higher yield where deep soil moisture was depleted indicates that extraction of deep soil moisture is important. [27]

Stay-green in wheat has potential to improve yield independently of root traits. [28]

Soil water can be effectively monitored to assist managers with crop decisions. However, using available technologies, it is unrealistic to think that highly accurate estimates of plant-available water will be possible given the inherent variability of northern cropping soils and current sensor technologies. [29]

More information

http://www.grdc.com.au/~/media/3AA0BA9C5D6E4EED8BF0C3313B0AD498.pdf

Technologies to support decision-making

In this context, several technologies will provide a level of information useful in decision-support without excessive investment.

Devices for soil monitoring

In-situ devices that have relatively small zones of measurement and rely on good soil–sensor contact to measure soil water are at a disadvantage in shrink–swell soils where soil movement and cracking are typical. This is more important in dryland than irrigated systems as seasonal soil water levels vary from above field capacity through to wilting

26 R Brill, G McMullen, M Gardner (2012) The effect of sowing depth on the establishment of several commercial wheat varieties. Australian Society of Agronomy/The Regional Institute Ltd, http://www.regional.org.au/au/asa/2012/crop-production/8196_brillr.htm#TopOfPage

27 JT Christopher, AM Manschadi, GL Hammer, AK Borrell (2008) Developmental and physiological traits associated with high yield and stay-green phenotype in wheat. *Australian Journal of Agricultural Research* 59, 354–364.

28 GRDC (2014), Stay green in wheat has potential to improve yield independently of root traits. http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Stay-green-in-wheat-has-potential-to-improve-yield-independently-of-root-traits

29 N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers Goondiwindi March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/Practical-processes-for-better-soil-water-management

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/How-to-get-soil-water-from-your-EM38-field-measurements

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-how-to-for-getting-soil-water-from-your-EM38-field-measurements

point or lower. Consequently, the potentially high levels of error associated with cracking and soil movement and high levels of inherent soil variability mean that increased device replication would be necessary to achieve confidence in results. This comes at an increased capital cost. Some devices (capacitance; time domain reflectometry, TDR) also have an upper measurement limit over which they are unable to accurately measure soil water. This may be a problem on high clay soils where moisture content at drained upper limit is likely to be >50% volumetric, the common limit for these devices.

By comparison, the use of a portable electromagnetic induction (EMI) device to measure bulk electrical conductivity and calculate soil water has a number of advantages. The EMI is quick, allowing for greater replication, measures the soil moisture of a large volume of soil (to 150 cm depth), is not affected by cracking or soil movement, and does not require installation of an access tube, thus making it available for use on multiple paddocks. However, it is unsuitable for use in saline soils and does not apportion soil water to particular layers within the soil profile. [30]

New thoughts on soil moisture monitoring

Despite an extensive range of monitoring instruments now available, measuring paddock soil moisture is still a considerable challenge. Among the suite of instruments currently on offer, one that is increasingly being used by researchers and agronomists is the EM38 (Geonics Ltd, Ontario, Canada). This electromagnetic induction instrument is proving to have significant application potential for determining soil properties useful in precision agriculture and environmental monitoring. It is now commonly used to provide rapid and reliable information on properties such as soil salinity and soil management zones, both of which relate well to crop yield. It is also used widely in agronomic and environmental applications to monitor soil water within the root-zone. It provides an efficient means to monitor crop water use and plant-available water (PAW) in the soil profile throughout the growing season so that informed management decisions can be made, e.g. the application, timing and conservation of irrigation water and fertiliser. EM38 datasets have also proved valuable to test and validate water balance models that are used to extrapolate to other seasons, management scenarios and locations.

The EM38 is an easy-to-use, geophysical surveying instrument that provides a rapid measure of soil electrical conductivity. Soil calibrations or qualitative assessments can be used to convert this to estimates of soil water in the root-zone. This information is vital to farm management decisions based on accurate knowledge of soil PAW. [31]

For more information, download: *A 'how to' for getting soil water from your EM38 field measurements*.

Calibration of monitoring devices

Electronic monitoring tools require calibration to convert the device output signal into information easily understood by the user, e.g. millivolts to volumetric soil water or PAW. This process requires the development of a relationship between sensor output and physically measured soil moisture content at moisture levels from dry to wet. The resulting calibration is then used to convert device output signal to gravimetric or volumetric water content.

To calculate the availability of soil moisture for crop use (in mm of available water) requires further processing of the data and knowledge of a soil's PAW capacity (PAWC). A suitable characteristic may be identified from the APSoil database or SoilMapp, or electronic sensor output may be used to identify the soil's water content operating range, to make reasonable assumptions on values for drained upper limit and crop lower limit. An alternative is to use Soil Water Express (Burk and Dalgliesh 2012), a tool

[30] N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers Goondiwindi March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

[31] J Foley (2013) A 'how to' for getting soil water from your EM38 field measurements. GRDC Update Papers Goondiwindi March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-how-to-for-getting-soil-water-from-your-EM38-field-measurements

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

which uses the soil's texture, salinity and bulk density to predict PAWC and to convert electronic sensor output to meaningful soil water information (mm of available water).

Modelling of soil water

Simulation of the water balance should be considered as an alternative to field-based soil water monitoring. Considering the error surrounding in-field measurement and issues with installation of sensing devices, there is a reasonable argument that the modelling of the water balance, when initialised with accurate PAWC and daily climate information, is likely to be as accurate as direct measurement. APSIM and Yield Prophet successfully predict soil water and they should be considered for both fallow and cropping situations. CliMate is a logical choice for managing fallow water (Freebairn 2012). [32]

Subsoil constraints

Soils with high levels of chloride and/or sodium in their subsurface layers are often referred to as having subsoil constraints. There is growing evidence that these affect wheat yields by increasing the lower limit of a crop's available soil water and thus reducing the soil's PAWC.[33]

Effect of strategic tillage

Research shows one-time tillage with chisel or offset disc in long-term, no-tillage helped to control winter weeds, and slightly improved grain yields and profitability, while retaining many of the soil quality benefits of no-till farming systems.

Tillage reduced soil moisture at most sites; however, this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received after tillage and prior to seeding and during the crop of that year. The occurrence of rain between the tillage and sowing or immediately after sowing is necessary to replenish soil water lost from the seed-zone. This suggests the importance of timing of tillage and of considering the seasonal forecast. Future research will determine the best timing for strategic tillage in no-till systems.[34] Note that these results are from one season and research is ongoing, so any impacts are likely to vary with subsequent seasonal conditions.

32 N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers Goondiwindi March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

33 Z Hochman *et al.* (2007) Simulating the effects of saline and sodic subsoils on wheat crops growing on Vertosols. *Australian Journal of Agricultural Research* 58, 802–810.

34 Y Dang, V Rincon-Florez, C Ng, S Argent, M Bell, R Dalal, P Moody, P Schenk (2013) Tillage impact in long term no-till. GRDC Update Papers Feb. 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till

More information

The strategic use of tillage in conservation

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till

Figure 10: Strategic tillage trials are underway at sites across the northern region. (Photo: Yash Dang)

1.7.2 Irrigation

Wheat responds well to irrigation. Critical periods for water are at tillering and flowering. Water requirements (in-crop) after starting with a full profile will be ~3 ML/ha. The WUE for wheat ranges between 10 and 20 kg/mm soil water.ha. As an example, if the expected yield output is 15 kg/mm and the yield target is 4.5 t/ha, the water required would be ~300 mm or 3 ML irrigation water/ha (assuming no in-crop rainfall and full moisture profile).

Irrigated wheat crops will normally require additional N fertiliser as follows:

- wheat or barley double-cropped after cotton or grain sorghum—140 kg N/ha
- wheat or barley double-cropped after maize—120 kg N/ha
- wheat or barley double-cropped after soybean or fallow—100 kg N/ha

Note: For protein levels of ≥11.5% in fully irrigated crops, a late application of N at booting would be necessary.

Consider near-infrared light plant tissue testing in-crop to determine side-dressing rates of N to obtain optimum yield and protein levels. [35]

Research into the methods of establishment used commercially in the production of irrigated wheat in the northern irrigated system produced highly variable results for seedling emergence.

Key findings included:

- Emergence rates can be quite consistent at ~80% if appropriate establishment methods are employed.
- Row spacing has minimal impact on crop yields up to, and in excess of, 8 t/ha.
- Nitrogen rates of >300 kg/ha were required to achieve yields >9 t/ha.

35 DAFF (2012) Wheat—planting information. Queensland Department of Agriculture Fisheries, and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Managing-resources-and-risk-for-8-tonne-cereal-crops

http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information

http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/managing-water-resources

- Plant growth regulator combinations have shown consistent yield increases, even in the absence of crop lodging. [36]

For more information, download the GRDC Update Paper, *Managing resources and risk for 8 tonne cereal crops.*

1.8 Yield and targets

Australia's climate, and in particular rainfall, is among the most variable on earth; consequently, crop yields vary from season to season. In order to remain profitable, crop producers must manage their agronomy, crop inputs, marketing and finance to match each season's yield potential. [37]

Before planting, identify the target yield required to be profitable:

- Do a simple calculation to see how much water you need to achieve this yield.
- Know how much soil water you have (treat this water like money in the bank).
- Think about how much risk your farm can take.
- Consider how this crop fits into your cropping plan, will the longer-term benefits to the system outweigh any short-term losses?
- Avoiding a failed crop saves money now and saves stored water for future crops. [38]

Figure 11: Before planting, identify the target yield. (Photo: Yash Dang)

Mobile applications (apps) are providing tools for ground-truthing precision agriculture data. Apps and mobile devices are making it easier to collect and record data on-farm. The app market for agriculture is evolving rapidly, with new apps becoming available

[36] B Griffiths, L Bailey, C Guppy, N Hulugalle, C Birchall (2013) Managing resources and risk for 8 tonne cereal crops. GRDC Update Papers 5 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Managing-resources-and-risk-for-8-tonne-cereal-crops

[37] T McClelland (2012) Yield-Prophet®—What difference can it make to crop decision making? GRDC Update Papers 6 February 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Yield-Prophet-What-difference-can-it-make-to-crop-decision-making

[38] J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Yield-Prophet-What-difference-can-it-make-to-crop-decision-making

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Managing-data-on-the-modern-farm

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Bridging-the-yield-gap

on a regular basis. For more information, download the GRDC Update paper, *Managing data on the modern farm.*

Bridging the yield gap

Wheat growers in the GRDC northern grain zone averaged 1.7 t/ha (Ya) over the 1996-2010 period. This represented 47% of the water limited yield (Yw) which could have been obtained under current technology with best practice and well adapted varieties.

Closing the exploitable yield gap (80% of Yw – Ya) would increase yields by 1.2 t/ha to raise the regional average to 2.9 t/ha.

The yield gap varies from season to season and from one statistical local area (SLA) to the next. CSIRO will be making these yield gap maps available online through a GRDC funded project so that farmers and their advisers can examine their own yields relative their farms' location.

Farmers can use these maps as a benchmarking tool. Are they achieving better or worse than their SLA's average yields over the same period? How close are they to closing the exploitable yield gap and consistently achieving a relative yield of 80%?

Advisers could challenge themselves to diagnose the cause of the yield gap for those clients who have large exploitable yield gaps.

See http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Bridging-the-yield-gap.

Yield Prophet®

Scientists have aimed to support farmers' capacity to achieve yield potential by developing the Agricultural Production Systems Simulator (APSIM). APSIM is a farming systems model that simulates the effects of environmental variables and management decisions on crop yield, profits and ecological outcomes.

Yield Prophet delivers information from APSIM to farmers (and consultants) to aid their decision-making. Yield Prophet has enjoyed a measure of acceptance and adoption amongst innovative farmers and has made valuable impacts in terms of assisting farmers to manage climate variability at a paddock level.

Yield Prophet is an online crop production model designed to present grain growers and consultants with real-time information about their crops. This tool provides growers with integrated production risk advice and monitoring decision-support relevant to farm management.

Operated as a web interface for APSIM, Yield Prophet generates crop simulations and reports to assist decision-making. By matching crop inputs with potential yield in a given season, Yield Prophet subscribers may avoid over- or under-investing in their crop. The simulations provide a framework for farmers and advisers to:

- forecast yield
- manage climate and soil water risk
- make informed decisions about N and irrigation applications
- match inputs with the yield potential of their crop
- assess the effect of changed sowing dates or varieties
- assess the possible effects of climate change

Farmers and consultants use Yield Prophet to match crop inputs with potential yield in a given season. This is achieved primarily by conducting scenario analyses in which the effects of alternative management options on crop yield and potential profitability can be assessed and applied, and can thereby influence decision-making.

How does it work?

Yield Prophet generates crop simulations that combine the essential components of growing a crop including:

- a soil test sampled prior to planting
- a soil classification selected from the Yield Prophet library of ~1000 soils, chosen as representative of the production area
- historical and active climate data taken from the nearest Bureau of Meteorology (BOM) weather station
- paddock-specific rainfall data recorded by the user (optional)
- individual crop details
- fertiliser and irrigation applications during the growing season

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Yield-Prophet-What-difference-can-it-make-to-crop-decision-making

http://www.soilquality.org.au/calculators/yield_potential

1.8.1 Seasonal outlook

Growers and advisers now have a readily available online tool. CropMate was developed by NSW Department of Primary Industries and can be used in pre-season planning to analyse average temperature, rainfall and evaporation. It provides seasonal forecasts and information about influences on climate, such as the impact of Southern Oscillation Index (SOI) on rainfall. The CropMate decision tool provides estimates of soil-water and N, frost and heat risk, as well as gross margin analyses of the various cropping options.

Download CropMate from the App Store on iTunes at: https://itunes.apple.com/au/app/cropmate-varietychooser/id476014848?mt=8

Figure 12: Screen shot of CropMate app. (Photo: NSW DPI)

Queensland Alliance for Agriculture & Food Innovation produces regular, seasonal outlooks for wheat producers in Queensland. These high-value reports are written in an easy-to-read style and are free. Download the *Seasonal Crop Outlook—wheat, October 2013*. For tips on understanding weather and climate drivers, including the SOI, visit the Climate Kelpie website. Case studies of 37 farmers across Australia recruited as Climate Champions as part of the Managing Climate Variability R&D Program can also be accessed at the Climate Kelpie website.

More information

http://www.qaafi.uq.edu.au/seasonal-crop-outlook-wheat

http://www.qaafi.uq.edu.au/content/Documents/crop-outlook/wheat/2013-10-wheat-outlook.pdf

http://www.climatekelpie.com.au/understand-climate/weather-and-climate-drivers/queensland#ElNino

http://www.climatekelpie.com.au/ask-a-farmer/climate-champion-program

Australian CliMate is a suite of climate analysis tools delivered on the web, iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records to ask questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, and well as El Nino Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather.

Download from the Apple iTunes store at: https://itunes.apple.com/au/app/australian-climate/id582572607?mt=8 or visit http://www.australianclimate.net.au

One of the CliMate tools, '*Season's progress?',* uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. It explores the readily available weather data, compares the current season with the long-term average, and graphically presents the spread of experience from previous seasons.

Crop progress and expectations are influenced by rainfall, temperature and radiation since planting. *Season's progress?* provides an objective assessment based on long-term records:

- How is the crop developing compared to previous seasons, based on heat sum?
- Is there any reason why my crop is not doing as well as usual because of below-average rainfall or radiation?
- Based on seasons progress (and starting conditions from Howwet–N?), should I adjust inputs?

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data

www.australianclimate.net.au

For inputs, *Season's progress?* asks for the weather variable to be explored (rainfall, average daily temperature, radiation, heat sum with base temperatures of 0, 5, 10, 15 and 20°C), a start month and a duration.

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [39]

The Bureau of Meteorology has recently moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate variables. [40]

1.8.2 Fallow moisture

For a growing crop there are two sources of water: first, the water stored in the soil during the fallow, and second, the water that falls as rain while the crop is growing. As a farmer, you have some control over the stored soil water; you can measure how much you have before planting the crop. Long-range forecasts and tools such as the SOI can indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it. [41]

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

Cover crops

During the 14-month-long fallow that arises when moving from summer to winter crops, stubble breakdown can denude the soil surface and leave it vulnerable to erosion. Cover crops of millet have been proposed as a solution, but this raises the question, how often is there sufficient water in the system to grow a cover crop without reducing the soil water reserves to the detriment of the following wheat crop?

39 Australian CliMate—Climate tools for decision makers, www.australianclimate.net.au

40 J Sabburg, G Allen (2013) Seasonal climate outlook improvements changes from historical to real time data. GRDC Update Papers 18 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data

41 J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

An on-farm research approach was used to compare the traditional long fallow (TF) with a millet fallow (MF) in 31 commercial paddocks over 3 years. Each treatment was simulated using the simulation-modelling framework APSIM to investigate the outcomes over a longer timeframe and to determine how often a millet fallow could be successfully included within the farming system.

The trials showed that early-sown millet cover crops removed before December had no effect on wheat yield, but this was not true of millet cover crops allowed to grow through to maturity. Long-term simulations estimated that a spring cover crop of millet would adversely affect wheat yields in only 2% of years if planted early and removed after 50% cover had been achieved. [42]

HowWet?

HowWet? is a program that uses records from a nearby weather station to estimate how much PAW has accumulated in the soil and the amount of organic N that has been converted to an available nitrate during a fallow. Howwet? tracks soil moisture, evaporation, runoff and drainage on a daily time-step. Accumulation of available N in the soil is calculated based on surface soil moisture, temperature and soil organic carbon.

HowWet?:

- estimates how much rain has been stored as plant-available soil water during the most recent fallow period;
- estimates the N mineralised as nitrate-N in soil; and
- provides a comparison with previous seasons.

This information aids in the decision about what crop to plant and how much N fertiliser to apply.

Many grain growers are in regions where stored soil water and nitrate at planting are important in crop management decisions. This is of particular importance to northern Australian grain growers with clay soils where stored soil water at planting can constitute a large part of a crop's water supply.

Questions this tool answers:

- How much longer should I fallow? If the soil is near full, maybe the fallow can be shortened.
- Given my soil type and local rainfall to date, what is the relative soil moisture and nitrate-N accumulation over the fallow period compared with most years? Relative changes are more reliable than absolute values.
- Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply? [43]

Inputs

- A selected soil type and weather station
- An estimate of soil cover and starting soil moisture
- Rainfall data input by the user for the stand-alone version of HowOften?

Outputs

- A graph showing plant-available soil water for the current year and all other years and a table summarising the recent fallow water balance
- A graph showing nitrate accumulation for the current year and all other years

[42] JPM Whish, L Price, PA Castor (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.

[43] Australian CliMate—How Wet/N, http://www.australianclimate.net.au/About/HowWetN

Reliability

HowWet? uses standard water-balance algorithms from HowLeaky? and a simplified nitrate mineralisation based on the original version of HowWet? Further calibration is needed before accepting with confidence absolute value estimates.

Soil descriptions are based on generic soil types with standard organic carbon (C) and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation. [44]

More information

http://www.australianclimate.net.au/About/HowWetN

1.8.3 Water-use efficiency

Water-use efficiency is the measure of a cropping system's capacity to convert water into plant biomass or grain. It includes the use of water stored in the soil and rainfall during the growing season.

Water-use efficiency relies on:

- the soil's ability to capture and store water;
- the crop's ability to access water stored in the soil and rainfall during the season;
- the crop's ability to convert water into biomass; and
- the crop's ability to convert biomass into grain (harvest index).

Water is the principal limiting factor in rain-fed cropping systems in northern Australia. The objective of rain-fed cropping systems is to maximise the proportion of rainfall that crops use, and minimise water lost through runoff, drainage and evaporation from the soil surface and to weeds.

Rainfall is more summer-dominant in the northern region, and both summer and winter crops are grown. However, rainfall is highly variable and can range, during each cropping season, from little or no rain to major rain events that result in waterlogging or flooding.

Storing water in fallows between crops is the grower's most effective tool to manage the risk of rainfall variability, as in-season rainfall alone, in either summer or winter, is rarely enough to produce a profitable crop, especially with high levels of plant transpiration and evaporation.

Fortunately, many cropping soils in the northern region have the capacity to store large amounts of water during the fallow. [45]

More information

http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

Fallow efficiency: the efficiency with which rainfall during a fallow period is stored for use by the following crop.

$$\text{Fallow efficiency (\%)} = \frac{\text{change in plant available water during the fallow x 100}}{\text{fallow rainfall (mm)}}$$

Crop water use efficiency: the efficiency with which an individual crop converts water transpired (or used) to grain.

$$\text{Crop WUE (kg/ha/mm)} = \frac{\text{grain yield (kg/ha)}}{\text{crop water supply (mm)} - \text{soil evaporation}}$$

Systems water use efficiency: the efficiency with which rainfall is converted to grain over multiple crop and fallow phases.

$$\text{SWUE (kg grain/mm rainfall)} = \frac{\text{total grain yield (kg)}}{\text{total rainfall (mm)}}$$

Ways to increase yield

In environments such as western NSW where yield is limited by water availability, there are four ways of increasing yield (Passioura and Angus 2010):

1. Increase the amount of water available to a crop (e.g. good summer weed control, stubble retention, long fallow, sowing early to increase rooting depth).

[44] Australian CliMate—How Wet/N, http://www.australianclimate.net.au/About/HowWetN

[45] *GRDC (2009) Water use efficiency—converting rainfall to grain. GRDC Fact Sheet Northern Region,* http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Strategies-for-improving-wateruse-efficiency-in-western-regions-through-increasing-harvest-index

2. Increase the proportion of water that is transpired by crops rather than lost to evaporation or weeds (e.g. early sowing, early N, vigorous crops & varieties, narrow row spacing, high plant densities, stubble retention, good weed management).
3. Increase the efficiency with which crops exchange water for carbon dioxide to grow dry matter, i.e. transpiration efficiency (e.g. early sowing, good nutrition, high transpiration efficiency varieties such as Spitfire⊕, Scout⊕, Drysdale⊕, Gregory⊕).
4. Increase the total proportion of dry matter that is grain, i.e. improve harvest index (e.g. early-flowering varieties, delayed N, wider row spacing, low plant densities, minimising losses to disease, high harvest index varieties such as H45 ⊕, Hindmarsh⊕, Wyalkatchem⊕, Espada⊕).

The last three of these all improve WUE. [46]

Knowledge of evaporation for the northern growing region soils is limited yet it is the largest part of the water balance. Since 2010 Queensland Department of Natural Resources and Mines (DNRM) researchers have been measuring evaporation directly for a range of soils using lysimetry techniques. They found most, but not all, soils evaporate at a similar rate. There are significant interactions between soil water, climate and rainfall that influence this rate of evaporation. This data has been used to test current modelling assumptions, better parameterise models, and is now directly contributing to improving predictions of the soil water balance component of models such as APSIM, APSIM-SWIM, HowLeaky, and HowWet (via CLiMate), by providing more realistic responses for our soils and climates. For more information, visit http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/How-much-water-is-lost-from-northern-crop-systems-by-soil-evaporation[47]

The French–Schultz approach

In southern Australia, the French-Schultz model is widely used to provide growers with a benchmark of potential crop yield based on available soil moisture and likely in-crop rainfall.

In this model, potential crop yield is estimated as:

Potential yield (kg/ha) = WUE (kg/ha.mm) x [crop water supply (mm) – estimate of soil evaporation (mm)]

where crop water supply is an estimate of water available to the crop, i.e. soil water at planting plus in-crop rainfall minus soil water remaining at harvest.

In the highly variable rainfall environment in the northern region, it is difficult to estimate in-crop rainfall, soil evaporation and soil water remaining at harvest. However, this model may still provide a guide to crop yield potential (see Tables 6 and 7).

The French–Schultz model has been useful in giving growers performance benchmarks—where yields fall well below these benchmarks, it may indicate something wrong with the crop's agronomy or a major limitation in the environment. There could be hidden problems in the soil such as root diseases, or soil constraints affecting yields. Alternatively, apparent underperformance could be simply due to seasonal rainfall distribution patterns, which are beyond the grower's control. [48]

46 J Hunt, R Brill (2012) Strategies for improving water-use efficiency in western regions through increasing harvest index. GRDC Update Papers 10 April 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Strategies-for-improving-wateruse-efficiency-in-western-regions-through-increasing-harvest-index

47 GRDC (2014), How much water is lost from northern crop systems by soil evaporation. http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/How-much-water-is-lost-from-northern-crop-systems-by-soil-evaporation

48 *GRDC (2009) Water use efficiency—converting rainfall to grain. GRDC Fact Sheet Northern Region,* http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

Table 6: Typical parameters that could be used in the French–Schultz equation

Crop	WUE (kg/ha.mm)	Soil evaporation (mm)
Wheat	18	100
Chickpea	12	100
Sorghum	25	150

Table 7: Effect of soil water threshold for planting on system water-use efficiency and other system performance parameters

System:		Conservative	Moderate	Aggressive
Planting threshold	mm	150	100	50
Number of crops		35	45	72
Crops/year		0.69	0.88	1.41
Total grain produced	t/ha	141	172	197
Average yield	t/ha	4.04	3.82	2.73
Average cover	%	40%	49%	55%
SWUE	kg/ha.mm	4.55	5.53	6.32
% rainfall ending up as:				
Transpiration		21%	26%	32%
Evaporation		56%	55%	55%
Run-off		18%	16%	11%
Drainage		5%	3%	2%

This table presents the results of a simulation modelling analysis for a cropping system at Emerald from 1955 to 2006.

More information

http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

Challenging the French-Schultz model

Application of the French-Schultz model for the northern region has been challenged in recent times.

In the wheat-belt of eastern Australia, rainfall shifts from winter-dominated in the south (South Australia, Victoria) to summer-dominated in the north (northern NSW and Queensland). The seasonality of rainfall, together with frost risk, drives the choice of cultivar and sowing date, resulting in a flowering time between October in the south and August in the north.

In eastern Australia, wheat crops are therefore exposed to contrasting climatic conditions during the critical period for grain formation, i.e. a window of about 20 days before and 10 days after flowering, which affects yield potential and WUE.

Understanding how those climatic conditions affect crop processes and how they vary from north to south and from season to season can help growers and consultants to set more realistic target yields across sites, locations and seasons (Figure 13).

Researchers have analysed some of the consequences of the shift from winter to summer rainfall between southern and northern regions in terms of implications for management and breeding. They advise caution on the use of simple rules of thumb (French–Schultz) for benchmarking WUE, and discuss the importance of more integrative and dynamic modelling approaches to explore alternatives to increase WUE at the single-crop and whole farming systems level (i.e. $/ha.mm).

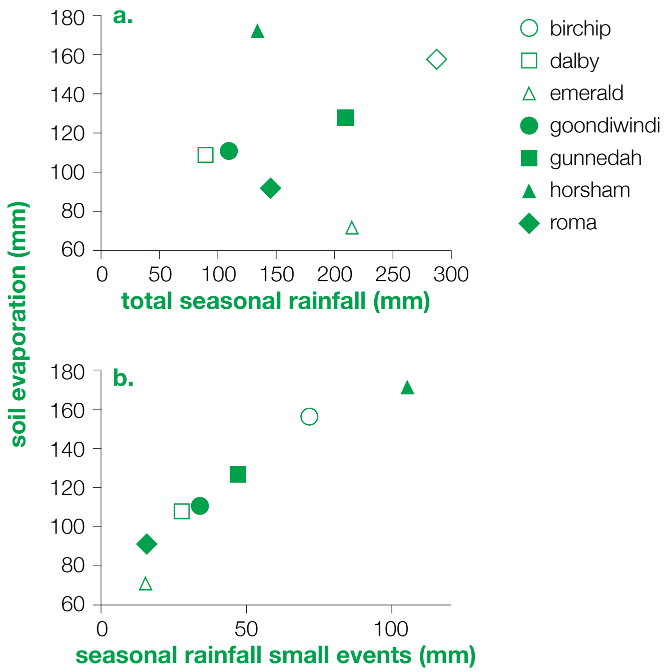


Figure 13: Simulated soil evaporation is (a) unrelated to seasonal rainfall and (b) closely related to rainfall in small events (i.e. equal or below 5 mm).

More information

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Farming-systems-design-and-water-use-efficiency-WUE-Challenging-the-French-Schultz-Wue-model

1.8.4 Nitrogen-use efficiency

Soil type, rainfall intensity and the timing of fertiliser application largely determine N losses from dryland cropping soils.

In cracking clay soils of the northern grains region, saturated soil conditions between fertiliser application and crop growth can lead to significant losses of N from the soil through denitrification. The gases lost in this case are nitric oxide, nitrous oxide and di-nitrogen (N_2). Isotope studies in the northern region have found these losses can be >30% of the N applied. Direct measurements of nitrous oxide highlight the rapidity of loss in this process.

Insufficient rainfall after surface application of N fertilisers can result in losses from the soil through volatilisation. The gas lost in this case is ammonia. Direct measurements of ammonia losses have found that they were generally <15% of the N applied, even less in in-crop situations. An exception occurred with the application of ammonium sulfate to soils with free lime at the surface, where losses were >25% of the N applied. Recovery of N applied in-crop requires sufficient in-crop rainfall for plant uptake from otherwise dry surface soil. [49]

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Nitrogen-use-efficiency

A balance of nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients P and N. Lack of other essential plant nutrients may also limit production in some situations.

Knowledge of the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand.

1.8.5 Double-crop options

The effects of tillage practice and double-cropping on growth, yield and N economies of summer crops were examined in field experiments near Tamworth, northern NSW, in the early years of minimum tillage.

49 G Schwenke, P Grace, M Bell (2013) Nitrogen use efficiency. GRDC Update Papers 16 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Nitrogen-use-efficiency

Sorghum, sunflower, soybean, mungbean, cowpea and pigeon pea were sown into alkaline, black earth soils that contained high (Site A, sown January 1983), moderate (Site B, sown December 1983), or low concentrations of nitrate (Site C, sown December 1984). During the previous winters, the land had been sown to wheat (double-crop), or fallowed using cultivation or no-tillage practices.

At Sites A and B, dry matter yields, averaged over all crops, were increased by 34 and 14% under no-tillage. Average increases in grain yields at the two sites were 22 and 11%. At Site C, tillage practice did not affect yields. Soybean showed the greatest responses to no-tillage. Increases in grain yields were 46, 15 and 18% for Sites A, B and C, respectively. The least responsive legume was mungbean. Yields of sorghum were increased by 41% at Site A; responses at Sites B and C ranged between a 9% decrease and a 7% increase.

With double cropping, grain yields were, on average, 18 (Site A), 81 (Site B) and 72% (Site C) of the yields in the cultivated (fallow) plots. However, when comparisons were made for the 12-month periods, i.e. wheat and summer crops *v.* fallow and summer crops, production was more than doubled at Site B and tripled at Site C, compared with the cultivated fallow. Rainfall of 192 mm (Site B) and 230 mm (Site C) during November and December replenished the soil profile with water to a depth of >0.75 m and was significant in the responses to double-cropping.

Assessments of soybean N_2 fixation using the ureide method indicated large effects of site and season on the proportion of plant N derived from N_2 fixation (range 0–0.83), on the amount of N_2 fixed (range 0-233 kg N/ha) and on the N balance as a result of the cropping (range, –69 to 45 kg N/ha).

No-tillage techniques are often used because of the need to sow immediately after harvest of the previous crop. The practice is common in the higher rainfall areas in the eastern half of the USA and may develop in the wetter, coastal regions of NSW with the expansion of soybean. Berndt and White (1976) performed a simulated water-balance study where the decision to sow the double-crop was made based on availability of soil water. They showed that double-cropping resulted in more frequent cropping (47 crops in 30 years), higher gross margins, lower water runoff, and reduced erosion hazard compared with continuous wheat (28 crops in 30 years) in a moderate (670 mm) rainfall environment in south-eastern Queensland. Only in a dry environment (520 mm annual rainfall) did continuous wheat produce higher gross margins than double-cropping. On the north-west slopes and plains, it is common for 700–800 mm of rain to fall during the 14-month fallow between sorghum harvest and the following wheat crop, a high proportion of which is not stored in the soil profile, but lost as runoff . Under these conditions, opportunity double-cropping is likely to succeed if there is a reasonable amount of water already stored in the soil at the time of sowing, e.g. water to a depth of 60–90 cm.

One of the major limitations of double cropping, however, might be the reduced availability of soil N because of the shortened fallow period and the absence of tillage. Crop legumes could play a key role here. In fact, lower concentrations of nitrate in no-tilled and double-cropped soils may be beneficial to legume N_2 fixation and, in some cases, to legume yields. Soil nitrate depresses nodulation of, and N_2 fixation by, legumes, the level of which depends primarily on the concentration of nitrate in the root-zone and to a lesser extent on the number of appropriate rhizobia in the rhizosphere. It also depends on the species of legume.

As predicted, wide-scale adoption of no-tillage cropping in northern NSW has led to a significant expansion of area sown to summer crops following the trends from the early (1979–83) trials.

While increased summer cropping may have little impact on the total area of land under crop, i.e. both winter and summer, it will increase flexibility at the farm level. Researchers also believe that opportunity double-cropping of summer crops may be economic when rainfall during the maturation of the winter crop is above average. Experiments were therefore commenced in 1981 at three sites near Tamworth, NSW, to compare production by summer crops under cultivated, no-tillage and double-cropping systems and to assess the effects of these systems on nodulation, on N_2 fixation and, ultimately, on N balances of the legumes in selected treatments. Effects of the pre-crop treatment, tillage and double-cropping on two subsequent crops of sorghum are the subject of the companion paper, Holland and Herridge (1992). [50]

Yields, grain protein contents and gross margins of wheat or sorghum (with several N rates) followed by chickpea or mungbean (with and without P fertiliser) were determined at a trial near Biloela in central Queensland. Nitrogen fertiliser increased grain protein and gross margin of wheat only when irrigated. Application of P fertiliser increased dry matter production at flowering of the pulses, but not the grain yield. The cereal-only rotation (0N) was the most profitable but not the most sustainable; N deficiency reduced yield and protein after three crops. The rotation with the cereal immediately followed by a pulse crop was profitable without the need for fertiliser N. When the pulses were grown on fallowed ground (with cereals being double-cropped), economic returns were as good as, and potentially greater than, the cereal–double-crop pulse rotation. Well-grown chickpea and mungbean crops contributed 51 and 41 kg N/ha, respectively, to the subsequent cereal.

Opportunity double-cropping is essential in central Queensland, especially when the soil profile is almost full prior to the intensive rainfall period. Double-cropping, especially with pulses after cereals, should be encouraged except when stored soil water contents are low. An alternative is to grow pulses on fallowed paddocks and double-crop the cereals when appropriate. This would result in higher pulse yields, moderate N_2 fixation if inherent soil N levels were low, and possibly reduced denitrification if the contributed N can be quickly incorporated into the cereal biomass. Disadvantages include low stubble levels of pulses increasing the risk of soil erosion, and a chance of greater price volatility.

Soil sampling, nutrient budgeting techniques and scenario analysis using crop models will increasingly assist decision-making. [51]

More information

http://www.regional.org.au/au/asa/1998/9/280cox.htm

1.9 Disease status of the paddock

1.9.1 Testing for disease

Stubble testing

Crown Analytical Services (Moree, NSW) provides commercial testing for crown rot. Some of the current strategies for management of crown rot are to control grass hosts prior to cropping, rotate susceptible cereals with non-host break crops, inter-row sowing, and grow tolerant wheat varieties. It is therefore very important for crown rot testing to be carried out on a paddock, so that growers and consultants can determine whether crown rot is present and if so, its severity. An informed decision can then be made regarding crop choice and farming system.

Testing involves a visual assessment on stubble followed by a precise plating test. This is the only way to accurately test for the disease. Results are provided to the grower and consultant within ~4 weeks of receiving the sample.

Crown Analytical Services provides sample bags and postage-paid packs. [52]

Check your cereal crops for crown rot between grain-fill and harvest. Collect plant samples from deep within the paddock by walking in a large ‘W’ pattern, collecting five plants at 10 different locations. Examine each plant for basal browning, record the

[50] DF Herridge, JF Holland (1992) Production of summer crops in northern New South Wales. 1. Effects of tillage and double cropping on growth, grain and N yields of six crops. *Australian Journal of Agricultural Research* 43, 105–122.

[51] HW Cox, WM Strong, DW Lack, RM Kelly (1998) Profitable double-cropping rotations involving cereals and pulses in central Queensland. Australian Agronomy Conference 1998. Australian Society of Agronomy/The Regional Institute Ltd, http://www.regional.org.au/au/asa/1998/9/280cox.htm

[52] Crown Analytical Services, https://sites.google.com/site/crownanalyticalservices/

More information

http://www.nga.org.au/results-and-publications/download/41/australian-grain-articles/diseases-1/crown-rot-tolerance-results-may-2009.pdf

http://www.grdc.com.au/uploads/documents/GRDC_CrownRot_North.pdf

https://sites.google.com/site/crownanalyticalservices/

percentage of plants showing the symptom and then put in place appropriate measures for next year. To see the honey/dark brown colour more easily, the leaf sheaths should be pulled back. This symptom may not appear on all stems of an infected plant and is difficult to see in oats.

As a general rule, the risk for a cereal in the next season will be:

- low, if <10% of plants infected
- medium, if 10–25% of plants infected
- high, if >25%t of plants are infected [53]

For more information and advice on the role of testing, contact your agronomist.

Soil testing

PreDicta B (B = broadacre) is a DNA-based soil testing service to identify which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding.

It has been developed for cropping regions in southern Australia and includes tests for:

- cereal cyst nematode
- take-all (*Gaeumannomyces graminis var. tritici* (Ggt) and *G. graminis var. avenae* (Gga))
- rhizoctonia barepatch (*Rhizoctonia solani* AG8)
- crown rot (*Fusarium pseudograminearum*)
- root lesion nematode (*Pratylenchus neglectus* and *P. thornei*)
- stem nematode (*Ditylenchus dipsaci*)

More information

https://sites.google.com/site/crownanalyticalservices/

http://www.sardi.sa.gov.au/products_and_services/entomology/diagnostic_services/predicta_b

Northern region grain producers can access **PreDicta B** via Crown Analytical Services or agronomists accredited by the South Australian Research and Development Institute to interpret the results and provide advice on management options to reduce the risk of yield loss. **PreDicta B** samples are processed weekly from February to mid-May (prior to crops being sown) to assist with planning the cropping program.

PreDicta B is not intended for in-crop diagnosis. That is best achieved by sending samples of affected plants to your local plant pathology laboratory.

1.9.2 Effects of cropping history

Continuous cereal cropping increases the risk of diseases including crown rot and tan spot. All winter cereals and many grassy weeds host crown rot, and it can survive for many years in infected plant residues. Infection can occur when plants come in close contact with those residues. [54]

More information

http://www.grdc.com.au/Media-Centre/Hot-Topics/Crown-Rot

Stubble burning is not recommended as a control for crown rot, and cultivation can increase incidence of seed–stubble contact. Inter-row sowing is a recommended strategy.

High cereal intensity and inclusion of durum wheat in cropping programs are factors that increase crown rot levels. [55]

53 www.grdc.com.au/uploads/documents/GRDC_CrownRot_North.pdf

54 GRDC (2012) Crown rot—about the crown rot disease. GRDC Hot Topics 10 July 2012, http://www.grdc.com.au/Media-Centre/Hot-Topics/Crown-Rot

55 GRDC (2012) Crown rot—about the crown rot disease. GRDC Hot Topics 10 July 2012, http://www.grdc.com.au/Media-Centre/Hot-Topics/Crown-Rot

1.10 Nematode status of the paddock

In the northern grain region, the predominant RLN, *Pratylenchus thornei,* costs the wheat industry AU$38 million annually. [56] Including the secondary species, *P. neglectus*, RLN is found in three-quarters of fields tested. [57]

1.10.1 Nematode testing of soil

It is important to have paddocks diagnosed for plant parasitic nematodes so that optimal management strategies can be implemented. Testing your farm will tell you:

- if nematodes are present in your fields and at what density
- which species are present

It is important to know which species are present because some crop-management options are species-specific. If a particular species is present in high numbers, immediate decisions must be made to avoid losses in the next crop to be grown. With low numbers, it is important to take decisions to safeguard future crops. Learning that a paddock is free of these nematodes is valuable information because steps may be taken to avoid future contamination of that field. [58]

Testing of soil samples taken either before a crop is sown or while the crop is in the ground provides valuable information.

1.10.2 Effects of cropping history on nematode status

Root-lesion nematode numbers build up steadily under susceptible crops and cause decreasing yields over several years. Yield losses >50% can occur in some wheat varieties, and up to 20% yield loss in some chickpea varieties. The amount of damage caused will depend on:

- the numbers of nematodes in the soil at sowing
- the tolerance of the variety of the crop being grown
- the environmental conditions

Generally, a population density of 2000 RLN/kg soil anywhere in the soil profile has the potential to reduce the grain yield of intolerant wheat varieties.

A tolerant crop yields well when high populations of RLN are present (the opposite is intolerance). A resistant crop does not allow RLN to reproduce and increase in number (the opposite is susceptibility).

Growing resistant crops is the main tool for managing nematodes. In the case of crops such as wheat or chickpea, choose the most tolerant variety available and rotate with resistant crops to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated in grower and DAFF planting guides. Note that crops and varieties have different levels of tolerance and resistance to *Pratylenchus thornei* and *P. neglectus* (Table 1).

For more information, download *Management of root-lesion nematodes in the northern grain region:* http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

Summer crops have an important role in management of root-lesion nematodes. Research shows when *P. thornei* is present in high populations two or more resistant

More information

https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

More information

https://sites.google.com/site/crownanalyticalservices/

http://www.sardi.sa.gov.au/products__and__services/entomology/diagnostic_services/predicta_b

http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

56 GM Murray, JP Brennan (2009)The current and potential costs from diseases of wheat in Australia. GRDC Report, https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

57 K Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

58 Queensland Primary Industries and Fisheries (2009) Root lesion nematodes—management of root-lesion nematodes in the northern grain region. Queensland Government, http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops. [59]

For more information on nematode management, see *Section 8: Nematodes*.

More information

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

1.11 Insect status of paddock

1.11.1 Insect sampling of soil

Soil-dwelling insect pests can seriously reduce plant establishment and populations, and subsequent yield potential.

Soil insects include:

- cockroaches
- crickets
- earwigs
- black scarab beetles
- cutworms
- false wireworm
- true wireworm

Different soil insects occur under different cultivation systems and farm management can directly influence the type and number of these pests:

- Weedy fallows and volunteer crops encourage soil insect build-up.
- Insect numbers decline during a clean long fallow due to lack of food.
- Summer cereals followed by volunteer winter crops promote the build-up of earwigs and crickets.
- High levels of stubble on the soil surface can promote some soil insects due to a food source, but this can also mean that pests continue feeding on the stubble instead of germinating crops.
- No-tillage encourages beneficial predatory insects and earthworms.
- Incorporating stubble promotes black field earwig populations.
- False wireworms are found under all intensities of cultivation but numbers decline if stubble levels are very low.

Soil insect control measures are normally applied at sowing. Since different insects require different control measures, the species of soil insects must be identified before planting.

Soil sampling by spade

1. Take a number of spade samples from random locations across the field.
2. Check that all spade samples are deep enough to take in the moist soil layer (this is essential).
3. Hand-sort samples to determine type and number of soil insects.

Germinating-seed bait technique

Immediately following planting rain:

1. Soak insecticide-free crop seed in water for at least 2 hours to initiate germination.
2. Bury a dessertspoon of the seed under 1 cm of soil at each corner of a 5 by 5 m square at five widely spaced sites per 100 ha.

59 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes. GRDC Update Papers Bellata 16 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

More information

http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects

http://www.pestgenie.com.au/

http://www.apvma.gov.au/

3. Mark the position of the seed baits, as large populations of soil insects can destroy the baits.
4. One day after seedling emergence, dig up the plants and count the insects.

Trials have shown no difference in the type of seed used for attracting soil-dwelling insects. However, use of the type of seed to be sown as a crop is likely to indicate the species of pests that could damage that crop.

The major disadvantage of the germinating-grain bait method is the delay between the seed placement and assessment.

Detecting soil-dwelling insects

Soil insects are often difficult to detect as they hide under trash or in the soil. Immature insects such as false wireworm larvae are usually found at the moist/dry soil interface.

For current chemical control options see the websites of Pest Genie Australia or APVMA. [60]

1.12 Mouse management

During years of high mouse activity young winter crops can be severely damaged. Growers need to monitor crops closely and determine if zinc phosphide baiting should be carried out to reduce damage to summer crops and protect newly sown winter crops. Growers are reminded that there is a two week withholding period for zinc phosphide baits prior to harvest. Talk to your neighbours and coordinate a baiting program to reduce reinvasion. [61]

60 DAFF (2011) How to recognise and monitor soil insects. Queensland Department of Agriculture, Fisheries and Forestry, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/help-pages/recognising-and-monitoring-soil-insects

61 Mouse plague prediction models: relevant forecasts for growers in Queensland http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Mouse-plague-prediction-models-relevant-forecasts-for-growers-in-Queensland