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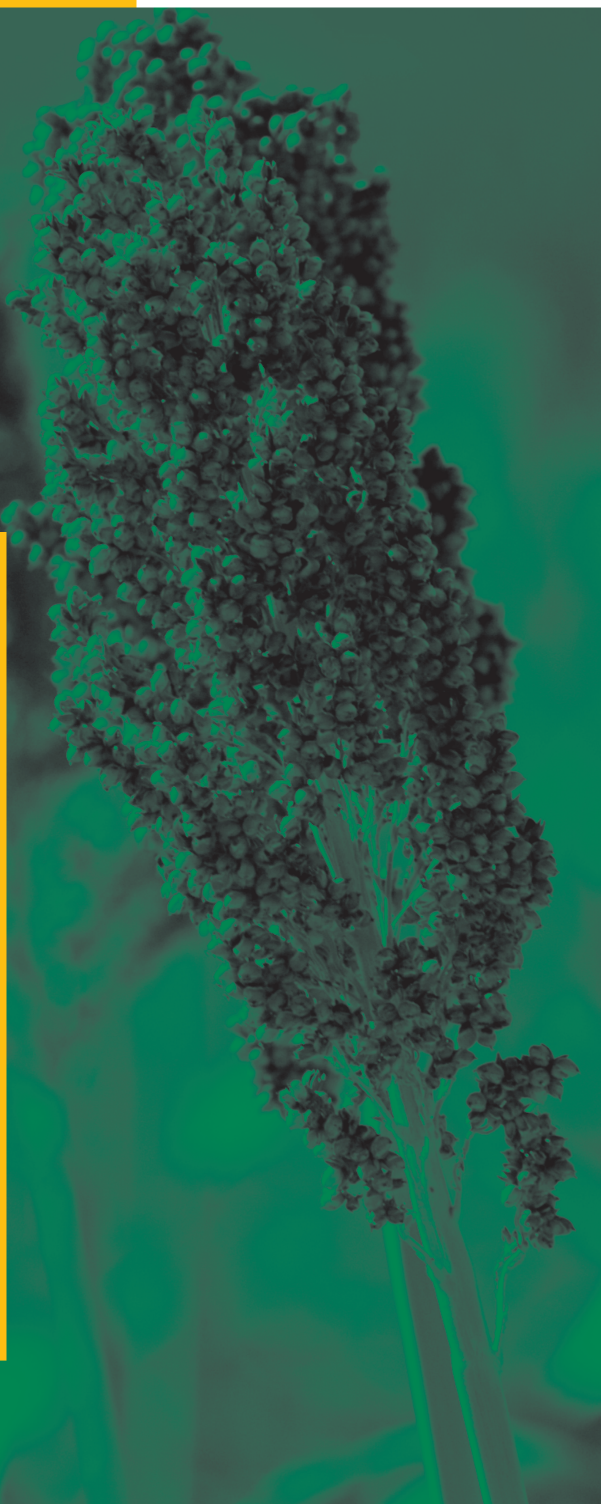
GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION



SORGHUM

SECTION 1

PLANNING AND PADDOCK PREPARATION

PADDOCK SELECTION | PADDOCK ROTATION AND HISTORY | BENEFITS OF SORGHUM AS A ROTATION CROP | DISADVANTAGES OF SORGHUM AS A ROTATION CROP | FALLOW WEED CONTROL | FALLOW CHEMICAL PLANT-BACK PERIODS | CROP ESTABLISHMENT | SOIL MOISTURE | YIELD AND TARGETS | NEMATODE STATUS OF THE PADDOCK | INSECT STATUS OF PADDOCK

Planning/Paddock preparation

1.1 Paddock selection

Grain sorghum, both dryland and irrigated, is usually grown on heavy clay soils with high water-holding capacity that are capable of supplying the plant with moisture through the warm growing season, even in the absence of rainfall.

Wherever possible, use no-till and controlled traffic for dryland crops, as these methods increase soil moisture storage more rapidly and deeply than random-trafficked, conventionally cultivated fallows. This increase in moisture storage, combined with reduced soil compaction, leads to increased yields and Water Use Efficiency. Use response cropping in favourable dryland areas to reduce the risk of deep moisture drainage. [1]

No-till sorghum following winter cereals consistently yields ~0.5 t/ha more than conventional crops because no-till fallows store about an extra 30 mm of plant-available water (Figure 1). Cereal stubbles also provide high levels of groundcover and maximise protection against soil erosion in predominantly summer-rainfall environments. Using no-till and minimum-till fallows enables crops to be sown up to 7 weeks after rain. This widens the planting window, increasing the likelihood of sowing at an optimum time. It can also mean the difference between planting a crop or not.

Successful sorghum crops have been grown immediately after winter pulse crops, provided the soil is wet to a depth of 1 m. Growing sorghum crops immediately following canola or mustard is not advised as these brassica crops can have a strong allelopathic [2] effect and can reduce arbuscular mycorrhizal fungi (AMF) levels. [3]

Figure 1: *No-till sorghum crops following winter cereals consistently yield ~0.5 t/ha more than conventional crops.*

MORE INFORMATION

GRDC Update Paper: Is there an issue with sorghum following canola

MORE INFORMATION

Crop & Pasture Science: Differential response of wheat to retained crop stubbles

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/broadacre/summer-crops/sorghum/sorghum/grain-sorghum

1 NSW DPI (2005) Grain sorghum. Agfact P3.3.5. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

2 Allelopathy, Wikipedia, https://en.wikipedia.org/wiki/Allelopathy

3 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

MORE INFORMATION

http://www.publish.csiro.au/paper/AR9890255.htm

http://www.apsim.info/Documentation/TrainingManualsandResources/APSIMGeneralTrainingManual/CropRotations.aspx

http://www.regional.org.au/au/asa/2001/2/a/mccosker.htm

http://www.drylandcotton.com.au/wp-content/uploads/2012/02/Dryland-Cotton-Long-Term-Rotation-Option.pdf

1.2 Paddock rotation and history

CSIRO research examined long-term yields, nitrogen (N) uptake and responsiveness of grain sorghum following several crop rotation scenarios. Three lucerne rotations, an annual legume rotation, long fallowing, and continuous wheat growing were measured on a black earth and red clay in northern NSW.

The three lucerne rotations compared two methods of lucerne establishment (with or without a cover crop) and two methods of grazing management (short or extended grazing). There were large beneficial effects of lucerne leys on the first grain sorghum crop, whether they were measured as grain yield, N content of the foliage and grain, or N uptake.

The effect was much smaller in the second year but it increased in the third and fourth years, in direct relation to the rainfall during the sorghum flowering period. The effect was greater on the black earth than on the red clay, reflecting the much higher lucerne yields on the former soil.

Evidence indicated that the N contribution from lucerne after the first year was no greater than the N accumulated by long fallowing, and this was attributed to very low rainfall and lucerne yields during the 4-year ley period. The annual legume rotation suffered from drought and insect damage in most years, and following sorghum yields tended to be lower than those achieved by long fallowing.

Differences in the effects of establishment method and grazing management on total lucerne yields were reflected in the differences in subsequent grain sorghum yields. The largest differences were on the black earth, where extended grazing lowered the total yields of lucerne and subsequent grain sorghum. Sowing lucerne under wheat had little effect on total yields of lucerne or sorghum. [4]

1.3 Benefits of sorghum as a rotation crop

Sorghum is currently the most profitable grain crop in the higher rainfall areas of the northern grainbelt. If cotton prices improve, sorghum will still play a major part in an overall rotation strategy to diversify the summer crop planting and include a high-biomass input crop to help maintain soil organic matter levels.

A continuous sorghum-cropping system is likely to have more than twice the biomass (organic carbon) input than a wheat–long fallow–dryland cotton rotation.

In a higher rainfall farming system that includes dryland cotton, sorghum can be grown in the summer following cotton. If the winter season following cotton is dry, sorghum planting may be late rather than early, which reduces the chance of a double-crop change back to a winter crop. In years when there is average to good winter rain, it may be possible to plant dryland cotton after sorghum.

Profit margins show that sorghum may be almost as profitable as wheat in western growing regions if slightly more yield can be achieved to make up for a lower price.

Even if sorghum is not as profitable as wheat, there may be benefits in the cropping system. Having a summer crop as well as a winter crop spreads risk and the workload, which reduces demand for labour and machinery, and diversified farms can operate with smaller machinery. For example, a 2000-ha farm might need more than one planter and harvester if it grows only winter crop, whereas one machine may suffice if a significant area of summer crop is planted each year.

Rotation benefits can be substantial from a period of sorghum in a wheat-cropping system:

1. It can provide a disease break for wheat diseases, such as crown rot, and for nematodes.

4 ICR Holford (1989) Yields and nitrogen uptake of grain sorghum in various rotations, including lucerne, annual legume and long fallow. Australian Journal of Agricultural Research 40, 255–264, http://www.publish.csiro.au/paper/AR9890255.htm

MORE INFORMATION

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

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/07/EXPANDING-THE-GRAIN-SORGHUM-INDUSTRY

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

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/09/THE-RELATIVE-PERFORMANCE-AND-TARGETING-RELIABILITY-OF-SUMMER-CROPS-MAIZE-SUNFLOWERS-COMPARED-TO-GRAIN-SORGHUM

2. Control of difficult weeds, such as wild oats, sow thistle and fleabane, can be improved with summer–winter crop rotations.
3. Sorghum rotations can be used to help prevent herbicide resistance.
4. It is generally the highest biomass crop in the northern grains region, and carbon inputs can help to maintain soil organic matter. By comparison, a wheat–long fallow–dryland cotton system can deplete organic matter. [5]

1.3.1 The potential of sorghum in the western cropping zone

The Grains Research and Development Corporation (GRDC) is funding research trials into the potential of sorghum as a rotational crop for growers in north-western NSW.

Dryland grain sorghum production in north-western NSW is highly variable in terms of both area sown and tonnes produced. Typical farming systems are no-tillage and primarily winter-based with cereal-dominant rotations; this has led to major issues with crown rot (*Fusarium pseudograminearum*). Currently, the most reliable and profitable break crop is chickpeas; however, with concerns about *Pratylenchus thornei*, increasing herbicide resistance and climate variability, a profitable summer crop alternative is needed.

Sorghum producers in this area consider sorghum to be reasonably high risk, and in recent years have been disappointed in the lack of break crop benefits achieved when returning to wheat following sorghum.

Minimal dryland sorghum research has been conducted in this western zone (considered to be west of the Newell Highway) and has never focused on the interactions between crop management options, environmental conditions and hybrids. In the more favourable production areas in north-eastern Australia, research has shown that systems using skip configurations can reduce the risk of crop failure but often result in reduced yields (Whish *et al.* 2005) [6].

Commercially, the adoption of double skip-row sorghum has assisted in improving the reliability of sorghum in this zone. Under skip-row configurations, soil water in the unplanted area is conserved until later in the growing season when the crop is able to access these resources to fill grain (Abunyewa *et al.* 2010) [7]. There has been little research to validate this practice or determine appropriate plant populations and the impact of hybrids with differing traits such as tillering and staygreen on crop performance in the low-rainfall regions. In two high-yielding seasons, the impact of varying these three key factors, row configuration, plant population and hybrid type, was evaluated.

NSW Department of Primary Industries research shows that, on an early planting in high-yielding seasons where yield potential is >4.0 t/ha, solid plant configurations consistently produced the highest yields. Single-skip and super wide configurations produced yield results similar to each other but consistently lower than the solid plant. Double-skip configurations yielded considerably less than all other configurations under these conditions. The impact of configuration on grain yield in this study supports the findings of Whish *et al.* (2005) in higher yielding regions.

Populations of 30,000 plants/ha produced lower yields under the high-yielding seasons. Plant populations should target 50,000–70,000 established plants/ha. Commercially, populations of 70,000 plants/ha are not recommended, because no benefit was found over 50,000 plants/ha and additional seed costs would be incurred. The low tillering, high stay-green hybrids used in these experiments were unable to produce competitive yields in favourable seasons. Hybrids with moderate

5 P Wylie (2008) Managing sorghum for high yields—a blueprint for doubling sorghum production. GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Sorghum_HY.pdf

6 vJ Whish, G Butler, M Castor, S Cawthray, I Broad, P Carberry, G Hammer, G McLean, R Routley, S Yates (2005) Modelling the effects of row configuration on sorghum yield, reliability in north-eastern Australia, Australian Journal of Agricultural Research, 56, 11–23.

7 A Abunyewa, R Ferguson, C Wortmann, D Lyon, S Mason, R Klein (2010) Skip-row and plant population effects on sorghum grain yield. Agronomy Journal, 102(1), 296–302.

MORE INFORMATION

vArthur Gearon, grower at Chinchilla Queensland and GRDC northern panellist discusses the role of stay-green sorghum. GRDC Podcast: 122 The Right Water - the missing ingredient in successful spraying

MORE INFORMATION

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Sorghum-agronomy-for-profit-in-the-western-zone

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

to high levels of tillering responded more favourably to the improved seasonal conditions experienced in these 2 years.

On the Liverpool Plains in northern NSW, GRDC supported research conducted by the NSW Department of Primary Industries is examining the impact of plant population, row configuration, phosphorus and nitrogen (N) applications, hybrid selection and time of sowing on grain yield. [8]

Several trial sites have been established and monitored including Breeza and either Premer, Pine Ridge or Willow Tree depending on the season. Some clear results and recommendations have been generated from the Breeza trial over the past two years (2013–14 and 2014–15) which sorghum growers can use to help guide their future decision making on agronomic management.

Sowing in the 'ideal window' at the end of October–early November generated higher yields than the late sowing in December. In the 2013–14 season, the early sowing yielded 0.25 t/ha higher than the later planted crop.

Three hybrids were used, MR Buster, MR Scorpio and 85G33, with MR Buster included as a commercial check and the two other varieties as examples of recent release hybrids. Yield differences due to hybrid selection were small, with much larger yield differences resulting from varying crop nitrogen nutrition, row spacing, sowing time and plant density.

There was a noticeable response to N in the trials, with yield increasing in line with increases in the N rate at both times of sowing. In the earlier sown crops, the use of 200 kg N compared to nil nitrogen resulted in an additional 1.81 t/ha grain yield while in the late sown trials it resulted in an increase of 0.85 t/ha.

There was also a 1 t/ha increase in yield with the October plant as plant population increased from 50,000 to 75,000 plants/ha (3.01 t/ha versus 4.10 t/ha). However, there was no difference in yield between the 75,000 and 100,000 plants/ha treatments (4.1 t/ha and 4.17 t/ha). At the same time there was no significant response to varying population in the late sowing treatment (average yield 3.3 t/ha).

1.3.2 Sorghum preceding wheat

Benefits:

- 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 groundcover 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 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 probably the best current option, but must be offset with early spray-out and a longer fallow period for the subsequent double crop (usually chickpeas). In recent years, the use of Dual Gold® in the winter fallow followed by at plant application has significantly improved the control of late germinating wild oats.

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.

8 GRDC (2016) GRDC funding tackles sorghum yield questions, https://grdc.com.au/Media-Centre/Media-News/North/2016/07/GRDC-funding-tackles-sorghum-yield-questions

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 & 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 (average 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 outcome for wheat yield 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.

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. [9]

MORE INFORMATION

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

1.4 Disadvantages of sorghum as a rotation crop

Sorghum is recommended as a break crop in areas that have a winter-crop-dominated rotation, but the success is dictated by the amount of breakdown of the winter cereal stubble. Altering row configuration and population may improve the reliability of sorghum; however, it may also reduce the rate of decomposition of cereal stubble and reduce water accumulation during the fallow period and the break crop benefits. [10]

Sorghum planted on wide rows can hamper control of problematic grass weeds. Barnyard grass (*Echinochloa* spp.), liverseed grass (*Urochloa panicoides*) and more recently feathertop Rhodes grass (*Chloris virgata*) are the most common summer grass weeds of cropping in southern Queensland and northern NSW. They are also present in central Queensland.

These grasses are favoured in reduced-tillage systems, and have increased in prevalence in the last two decades. They are prolific seeders, are not consistently controlled with commonly used herbicides, and can be highly competitive. When uncontrolled, these weeds can reduce sorghum yields by 25–40%. [11]

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/ngrt-results

9 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

10 G McMullen *et al.* (2013) Sorghum in the western zone—Row Configuration × Population × Hybrid—"Morialta", Mungindi 2012, Northern grains region trial results, pp. 76–80. Autumn 2013. NSW Department of Primary Industries http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/ngrt-results

11 QDAF Management of barnyard and liverseed grasses. Department of Agriculture, Fisheries and Forestry, Queensland, http://www.daff.qld.gov.au/__data/assets/pdf_file/0008/55277/Managing-barnyard-and-liverseed-grasses.pdf

1.4.1 Sorghum in crop sequences

Because of their ability to survive from season to season in infected stubble, the levels of the charcoal rot and Fusarium stalk rot pathogens in a paddock will generally increase with consecutive sorghum crops. Where charcoal rot has been a problem, sunflower, dryland soybean and mungbean crops should be avoided in future crop sequences for at least 3 years to reduce charcoal rot levels, and consideration should be given to growing winter crops in the crop sequence.

The role that other minor or potential hosts, e.g. chickpeas, play in the survival of the charcoal rot pathogen is unknown. Almost nothing is known of the ability of the *Fusarium* stalk rotting pathogens to survive in the northern region and the role that residue from non-hosts plays in their survival. However, it would be prudent to rotate out of sorghum to a known non-host crop, e.g. winter cereals and pulses or summer broadleaf crops, if Fusarium stalk rot has become an issue in a paddock.

Sorghum should not planted into, or adjacent to, paddocks where the previous winter cereal crop was affected by Fusarium head blight (Table 1). Crop sequences specifically designed to minimise the risk from leaf diseases are unlikely be effective, because of the airborne nature of the pathogen's spores. [12]

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

MORE INFORMATION

Arthur Gearon, grower at Chinchilla Queensland and GRDC northern panellist discusses the impact of charcoal rot on sorghum yield and management options. GRDC Podcast: 122 The Right Water - the missing ingredient in successful spraying

1.4.2 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) (Figure 2). 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 periods of long fallow. As cropping programs restart after dry years, a yield drop is likely from reduced AM levels, making it difficult for the crop to access nutrients.

12 GRDC (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers 13 September 2011

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.

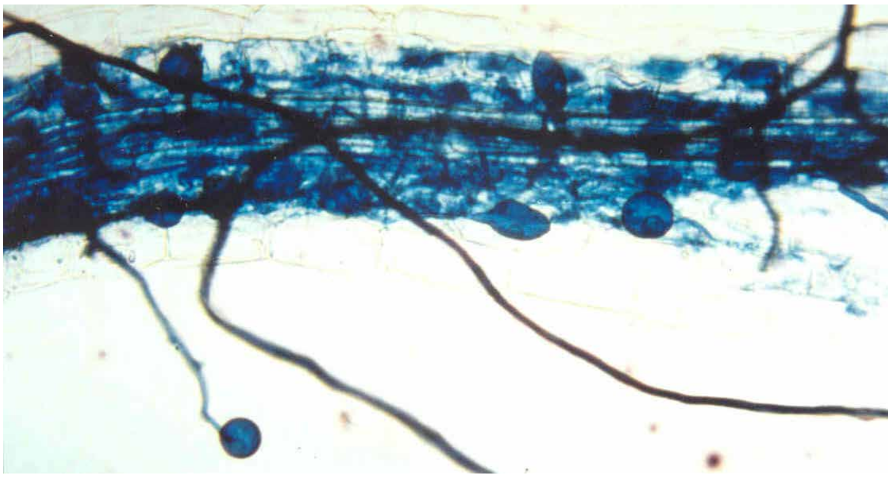


Figure 2: *Arbuscular mycorrhizae pictured in a wheat root.*

Photo: QDAF, Qld

MORE INFORMATION

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

Benefits of good AM levels are:

- improved uptake of P and Zn
- improved crop growth
- 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. Sorghum has a medium dependency on mycorrhiza, and crops with higher dependency benefit more from AM (Table 2). [13]

Table 2: *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

1.5 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 below for the most common problem weeds; however, for advice on individual paddocks, you should contact your agronomist.

13 QDAF (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

MORE INFORMATION

Chris Preston University of Adelaide discusses strategies behind managing weeds around paddock boundaries and along fencelines. Video: Weed control on paddock boundaries and fencelines

MORE INFORMATION

GRDC Update Paper: Pre-emergent herbicides part of the solution but much still to learn

MORE INFORMATION

Michael Widrig QDAF discusses glyphosate resistant weeds and weed management strategy. GRDC Podcast: 107 Summer weed control - the latest

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 is present that would support continued weed growth. [14]

The Northern Grower Alliance (NGA) is trialing methods to control summer grasses. Key findings include:

1. Weeds resistant and tolerant to glyphosate 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 buildup.

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 practice can also be applied in-crop. [15]

Consider the species present, interval timing and water rate. For information on double-knock tactics, download the GRDC 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) 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.

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. awnless barnyard grass (ABYG) (*Echinochloa colona*) (Figure 3)

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

15 C Borger, V Stewart, A Storrie. Double knockdown or 'double knock'. Department of Agriculture and Food Western Australia

2. flaxleaf fleabane (*Conyza bonariensis*)
3. feathertop Rhodes grass (FTR) (*Chloris virgata*)
4. windmill grass (*Chloris truncata*)

Awnless barnyard grass

Figure 3: *Awnless barnyard grass. Barnyard grass can be difficult to control in northern farming systems.*

Photo: Rachel Bowman, Seedbed Media

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 Department of Primary Industries (DPI), Department of Agriculture, Fisheries and Forestry Queensland (QDAF) 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 summer crops, e.g. metolachlor (e.g. Dual Gold®) and atrazine, or fallow, e.g. imazapic (e.g. Flame®), and these ingredients 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 an effective strategy in fallow. Growers and agronomists need to understand the plant-back implications of the residual herbicide options they choose to employ.

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 finer spray quality 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 such as mungbeans. Even on glyphosate-resistant ABYG, a double-knock of glyphosate followed by paraquat 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 4: *Flaxleaf fleabane.*

Photo: QDAF, Qld

There are three main species of fleabane in Australia: *Conyza bonariensis* (flaxleaf fleabane) (Figure 4), *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. [16]

For more than a decade, flaxleaf fleabane has been the major weed-management problem 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 knockdown 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 and fluroxypyr followed by paraquat are crucial tools 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.

16 M Widderick, H Wu. Fleabane. Department of Agriculture and Food Western Australia

MORE INFORMATION

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

https://www.agric.wa.gov.au/grains-research-development/fleabane

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, chickpeas 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)

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.

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. 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.

Feathertop Rhodes grass

Figure 5: *Feathertop Rhodes grass.*

Photo: Rachel Bowman

Feathertop Rhodes grass (Figure 5) 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 population explosions.

Key points

- Glyphosate alone or glyphosate followed by paraquat has generally poor efficacy, especially on more advanced plants.
- 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 blowouts.

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

Although a glyphosate followed by paraquat double-knock is an effective strategy against ABYG, 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 selection for resistance, 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.

Windmill grass

Figure 6: *Windmill grass.*

Photo: Maurie Street

Whereas FTR has been a grass weed threat coming from Queensland and heading south, windmill grass (Figure 6) is more of a 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 greatest 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 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. No products are currently 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 ≤1 day. Good control can often be obtained up to 21 days after the initial application. [17]

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

1.6 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). 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. [18]

For more information, see the NSW DPI publication 'Weed control in summer crops' at www.dpi.nsw.gov.au/pubs/wcsc.

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

http://www.caws.org.au/awc/2002/awc200210871.pdf

1.7 Crop establishment

Apart from moisture stress, poor crop establishment and weed competition are usually the major factors that significantly reduced sorghum yields. The following recommendations should help to improve crop establishment and crop yields.

Uniform establishment and accurate depth placement of seed is essential. Precision planters can achieve both of these, when correctly managed. Planters should be in small enough sections to follow the paddock undulations with large-diameter depth wheels located within the frame and tines or discs mounted on parallelogram planter units.

Narrow points or discs are better suited to no-till and minimum-till conditions and work very well in free-flowing soils, but excessive planting speeds will reduce establishment.

In moist seedbeds, the seed should be placed no more than 3 cm deep; depths greater than this will reduce emergence. In dry seedbeds using moisture seeking for deep-furrow planting, the seed is also placed 5 cm deep. In this instance, the seed

17 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

18 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.dpi.nsw.gov.au/agriculture/broadacre/guides/summer-crop-production-guide

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.regional.org.au/au/asa/2006/poster/water/4587_routleyr.htm

may be 10–12 cm below the original soil surface. Seeding practices that leave furrows above the seed are at risk of damage from storm rainfall. High-intensity rainfall can fill furrows with water; the damage from this type of event can be 3-fold:

1. Short term waterlogging can increase the risk of seedling diseases and slow the emergence.
2. Chemical damage. Water can carry herbicides used at planting into the furrow, concentrating them in the seed zone; combined with waterlogging, stands can be dramatically reduced.
3. Water flow into the furrow can also carry soil. This, combined with soil swelling, can increase the actual seed depth. This can reduce the emergence percentage depending on the depth and the above-mentioned stresses.

Press-wheels are essential not only to improve establishment but also to help control soil insect pests of germinating and emerging sorghum, including true and false wireworms. Use press-wheel pressures of 4–6 kg per cm width of press-wheel for conventional seedbeds and 6–10 kg for no-till and minimum-till seedbeds. Use pressures at the higher end of the range when sowing moisture is marginal, seed is deeply planted or soil insects are present. Use pressures at the lower end of the range when soils are hard-setting or surface-crusting. Crop establishment is improved when the shape of the press-wheel matches the shape of the seed trench. [19]

1.8 Soil moisture

1.8.1 Dryland

Planting sorghum with <1 m of wet soil reduces the likelihood of high yields, increases the risk of crop failure and places a greater reliance upon in-crop rain to produce an economic yield.

Crops sown on heavy clay soils with 1.5 m of wet soil and receiving 100 mm of effective in-crop rain should yield at least 3.5 t/ha, but crops starting with 1 m of wet soil plus 50 mm of effective rain will yield only ~1.3 t/ha. After the initial 100–110 mm of soil water is used, sorghum can produce grain at an approximate rate of 15 kg/ha.mm available soil water.

Using this Water Use Efficiency (WUE) estimate, producers with good management practices should be achieving long-term average yields in the Quirindi area of 5–6.8 t/ha; Gunnedah, Inverell and Tamworth districts 3.5–4.0 t/ha; Moree and Narrabri districts 2.5–3.0 t/ha; and Coonamble–Walgett districts 2.0–2.5 t/ha. [20]

For dryland production, fallow moisture storage is maximised by no-tillage and good stubble cover.

Many trials have shown that sorghum grown using no-tillage yields ~25% higher than sorghum on land that has been cultivated, providing nutrient supply is adequate for the higher yields.

Fallow trials at Billa Billa (Thomas 2000) provide an example of this yield gain, where for six sorghum crops grown between 1988 and 1995, grain yield improved from 2.48 t/ha when cultivated to 3.05 t/ha with no-till, an increase of 23%.

At Biloela in 1992, sorghum was double-cropped on wheat after 240 mm of rain was received in November and December. Rainfall between sowing and harvest was 62 mm, of which 50 mm fell prior to flowering. This meant that the crop had a dry finish. Grain yield for no-tillage was 2.4t/ha, compared with 1.27t/ ha for cultivated treatments.

19 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

20 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

MORE INFORMATION

http://www.ausgrain.com.au/Back%20Issues/195jfgrn10/22-sowing.pdf

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/THE-ECONOMICS-OF-SOWING-DECISIONS-AND-LIMITED-SOIL-WATER

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/MODELING-THE-PROFIT-AND-RISK-OUTCOMES-OF-A-RANGE-OF-SOIL-WATER-TRIGGERS-AND-CROPPING-AREA-INTENSITIES-GOONDIWINDI

MORE INFORMATION

GRDC Update Paper: Can high performance surface irrigation reduce nitrogen losses in broadacre cropping systems?

It was noted as unlikely that the tillage over 3 months resulted in this large yield difference. The response is attributed, at least in part, to the long-term effects of 10 years of no-tillage on the soil.

After 20 years of different tillage treatments, this trial area is showing ongoing benefits in soil health and yield of crops. Three crops have been grown using no-tillage, with the yield on land no-tilled for 20 years almost 90% higher than for crops grown using no-tillage but on land cultivated for 20 years (2.7 t/ha average yield *v.* 1.43 t/ha; Freebairn 2006).

As well as fallow storage, moisture utilisation during the growth of the sorghum crop is likely to be optimised by no-tillage. A higher level of groundcover will reduce runoff and slow evaporation.

Farmers have also found that no-tillage provides a much greater chance of using moisture-seeking planting for an early plant of sorghum on land fallowed from wheat.

Moisture stays closer to the surface, and in some cases it has been possible to plant sorghum in September, many weeks after the last fall of rain. [21]

1.8.2 Irrigation

An understanding of sorghum crop development and the environmental drivers of crop development is crucial if managers are to maximise the crop performance through irrigation. Irrigation timing is a critical part of irrigation management in grain sorghum, and whereas meeting the evaporative demand is also important, it can result in poor WUE if the irrigation is applied at the wrong time. In more favorable growing areas, strategic irrigations at key growth stages can result in very high yields and WUE.

Grain sorghum growth stages

The growth cycle of grain sorghum can be broken into three main stages (Figure 7):

1. Early growth: stages 0–2 or emergence to 5 leaves fully emerged
2. Vegetative growth: stages 3–5 or 8 leaves fully emerged to booting
3. Early grainfill; stages 6–7.5 or flowering to milky dough approximately 65–85 days after emergence [22]

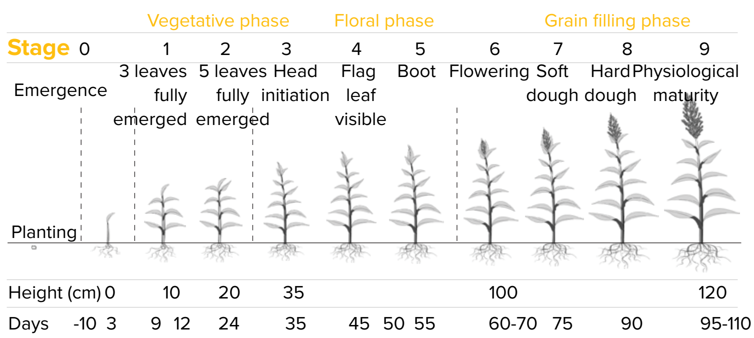

Figure 7: *Growth stages of sorghum.*

Quantities of water required for full irrigation of a sorghum crop will vary depending on seasonal and soil conditions; however, budget on 1.4 ML/ha (delivered to the field) for a pre-irrigation and three irrigations of 1.2 ML/ha during the growing season. The timing of the first irrigation in the absence of irrigations should be at flowering

21 P Wylie (2008) Managing sorghum for high yields—a blueprint for doubling sorghum production. GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Sorghum_HY.pdf

22 T Philp (2011) Irrigated grain sorghum agronomy; irrigation timing. GRDC Update Papers 7 September 2011

MORE INFORMATION

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

http://www.grdc.com.au/uploads/documents/GRDC_Water%20Use%20Efficiency%20.North%20version%20231009.pdf

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

http://www.moreprofitperdrop.com.au/wp-content/uploads/2013/10/WATERpak-4_2-Irrigated-Sorghum-best-practice.pdf

MORE INFORMATION

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

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

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

and 10–14 days later during early grainfill. Irrigated yields should be in the vicinity of 10–12 t/ha. [23]

1.9 Yield and targets

1.9.1 Seasonal outlook

Queensland Alliance for Agriculture & Food Innovation (QAAFI) produces regular, seasonal outlooks for sorghum producers. These high-value reports are written in an easy-to-read style and are free. For more information, visit https://qaafi.uq.edu.au/industry/crop-outlook.

For tips on understanding weather and climate drivers, including the Southern Oscillation Index (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.

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 Niño 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 season's progress (and starting conditions from HowWet–N?), should I adjust inputs?

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. [24]

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. [25]

23 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

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

25 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

MORE INFORMATION

Jeremy Whish CSIRO discusses target yield, soil water and planting in a dry year. GRDC Podcast: 063 Summer cropping

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Strategies for managing risk. Ground Cover Radio 121: Risk strategy likened to a big game of chess

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Ground Cover Issue 121: Risk strategy likened to a 'big game of chess'

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GRDC Update Paper: Optimising performance of current Northern cropping farming systems

1.9.2 Water Use Efficiency (WUE)

The WUE 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.

WUE relies on:

- the soils ability to capture and store water;
- the crop's ability to access water stored in the soil and rainfall during the season;
- the availability of water at key growth stages;
- the crop's ability to convert water into biomass; and
- the crop's ability to convert biomass into grain (harvest index). [26]

Converting water into grain

Crop factors indicate how a plant converts water into grain.

Using an average WUE factor of 15 (for every mm of water taken up by the plant, the crop will produce 15 kg grain/ha) for sorghum and assuming the plant uses all the rain that falls, a yield of ~1.7 t can be achieved from 115 mm of in-crop rainfall on average. A wide range of WUE has been measured in grain sorghum, from 7 to 25 kg/mm. The amount of water available is important, but equally important is the timing; other abiotic factors such as heat at key development stages can have major effect.

However, much of this rainfall will be lost from the system via evaporation, or in some cases, runoff. The amount lost is hard to predict and depends on the intensity of the rainfall, the soil dryness at the time of the rainfall event, and the length of time that radiation is reduced from cloud cover and crop cover. On average, ~50–75% of this water will be lost from the system. This changes the scenario from 1.7 t/ha to ~0.4–0.8 t/ha.

Water stored during the fallow is the second source of crop water supply. Stored water is of higher value than rainfall because it is available when the plant needs it, provided reserves are sufficient. In terms of risk management, the greatest value of stored water is in knowing the quantity available for crop production, even before the crop is planted, when decisions are being made. It is also why managing fallow stubble cover and weeds is so important.

Using the above example where the goal is to produce a crop in the region of 2.6–3 t/ha, the analysis of rainfall shows an 80% chance of growing at least 0.4–0.8 t on rainfall alone; therefore, the crop needs to derive the additional 2.2–2.6 t of planned production using the soil water reserves. With the crop factor of 15 kg grain/ha.mm water, this suggests that 140–170 mm of soil water will be required. In rough terms, 150 mm soil water should achieve a 20% return on input costs, or better, 8 years in 10.

The efficiency of production may actually be a lot lower (or higher) depending on seasonal rainfall distribution and crop stage. An alternative approach, which does take into consideration the vagaries of seasonal rainfall distribution and amount, temperature, radiation and soil condition, is to use simulation modelling tools such as APSIM, or its derivatives Yield Prophet™ or Whopper Cropper. These tools all use probability to describe the riskiness of particular actions such as planting on a particular date. Figure 8 shows an APSIM output prepared for Rowena, looking at an October planting.

26 GRDC (2009) Converting rainfall to grain. Northern Region. GRDC Water Use Efficiency Fact Sheet, http://www.grdc.com.au/uploads/documents/GRDC_Water%20Use%20Efficiency%20North%20version%20231009.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

http://www.grdc.com.au/Resources/Factsheets/2010/02/Water-Use-Efficiency-North

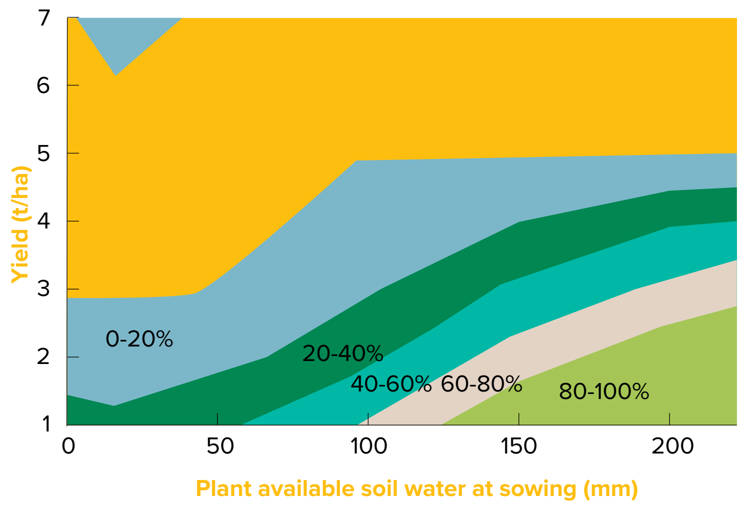

Figure 8: *Rainbow chart showing the probability (colours) of achieving a particular yield (y-axis) based on starting soil water conditions (x-axis). Moving left to right: red, 0%, yellow 0–20%, green 20–40%, light blue 40–60%, dark blue 60–80%, pink 80–100%.*

Figure 8 supports the back-of-envelope calculation suggesting that 150 mm of starting water is the minimum required to achieve a yield of 3 t in 5 years in 10, whereas with 200 mm of stored water the probabilities improve to 6–8 years in 10.

Different sowing strategies can be used to reduce the risk of a failed crop. Skip-row planting maintains a high plant density within the crop row, forcing the plants to experience early competition that limits tillering. As the plants approach grainfill, the limited number of tillers are filled from the spared water in the skip, ensuring the crop is finished. The advantage of skip-row is that it helps ensure a yield and prevents crop failure. However, the downside is that yield is capped because of the lack of tillers, so the crop cannot take full advantage of good rain and will yield less than a solid crop configuration when not under stress. High pricing may also be a consideration.

If the outlook is poor, reducing the area planted is also a way of hedging bets and reducing the risk and expense of a failed crop. However, growing a non-profitable crop as part of a rotation can be tolerated, provided the benefits of the crop to the overall farm system are justified. Reducing weeds, managing herbicide resistance and reducing disease inoculum are benefits of crop rotation that are not easily measured and not considered when using simple WUE calculations or crop model simulations.

Deciding whether to plant is difficult; experience and intuition are valuable components of this decision. However, by following some of the approaches presented here, the decision can be made more transparent and justifiable. By thinking about the consequences of the planting decision on future crops, and how this crop fits into the overall whole farm system, the best decision will be made. [27]

MORE INFORMATION

GRDC Update Paper: Sorghum yield risk vs starting soil moisture

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.

27 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

In this model, potential crop yield is estimated as:

Potential yield (kg/ha) = WUE (kg/ha.mm) × [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 3 and 4).

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. [28]

MORE INFORMATION

GRDC Update Paper: Managing the Yield Gap to achieve your yield potential in central west NSW

MORE INFORMATION

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

Table 3: *Typical parameters that could be used in the French–Schulz equation.*

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

Table 4: *Effect of soil water threshold for planting on system Water Use Efficiency (SWUE) 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

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.

28 *GRDC (2009) Converting rainfall to grain. Northern Region GRDC Water Use Efficiency Fact Sheet,* http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

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 9).

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.

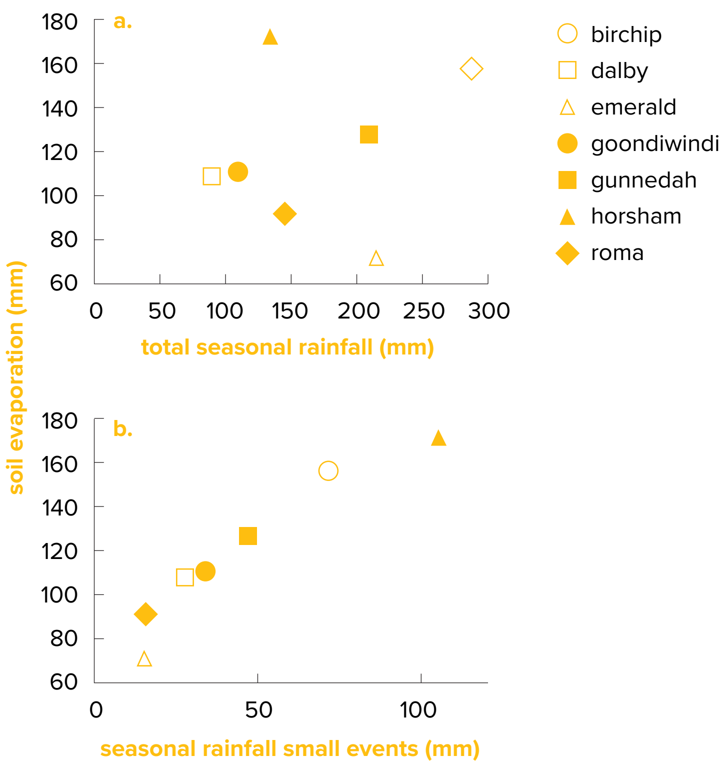

Figure 9: *Simulated soil evaporation is (a) unrelated to seasonal rainfall and (b) closely related to rainfall in small events (i.e. ≤5 mm).*

1.9.3 Nitrogen-use efficiency (NUE)

Although sorghum is a C4 crop [29] and uses N, CO_2, solar radiation and water more efficiently than most C3 crops, N as a nutrient is still one of major factors limiting crop yield. Depending on soil N fertility, applications to commercial grain sorghum crops can vary from 0 to 150 kg N/ha.

As yield increases and if there is a shortfall of N, grain protein will decline, sometimes by as much as 6 percentage points. The total N requirement of an 8 t/ha sorghum crop at a grain protein level of 6.5% is 142 kg N, compared with 190 kg N at 10%

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

29 C4 carbon fixation. Wikipedia, http://en.wikipedia.org/wiki/C4_carbon_fixation

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Agronomic-and-economic-responses-of-sorghum-to-nitrogen-nutrition

protein. It is generally thought that the maximum yield is achieved with grain protein at 9–10%, and that at lower levels yield is compromised by a lack of N.

Variable responses to the application of N fertiliser have previously been observed in sorghum, with differences attributed to climatic, soil and genotypic factors across seasons and locations. Part of this yield variation is associated with differences in the capability of the soil to supply N and in the efficiency of recovery of applied N fertiliser. The other component contributing to the variable yield response to fertiliser-N is the N requirement for yield determination. The N requirement is dependent on the yield expectation in a given environment as determined by climate, management and cultivar. There is a need to determine the minimum N requirement for a given yield level so as to maximise NUE (defined as grain yield per unit N uptake). Nitrogen uptake in excess of that required for yield determination results in lower NUE and is associated with increased stem and grain N concentration.

Sorghum is currently one of the most profitable crops in the higher rainfall areas of the northern grains belt. Profit margins suggest that sorghum may be almost as profitable as wheat in western growing regions if slightly more yield can be achieved to make up for a lower price. Nitrogen inputs represent a large input cost within the gross margin for sorghum; however, the lack of protein premiums means that luxurious N applications directly reduce profitability. [30]

Nitrogen loss pathways

Nitrogen can be lost from cropping soils via downwards, sidewards or upwards movement.

Downward movement of nitrate [NO_3^-] via leaching is a greater problem in lighter textured soils than in the medium–heavy clays dominating the northern grains zone, but previous research has demonstrated some N losses, albeit small on an annual scale, can occur via this pathway. [31]

Sideways movement can occur rapidly through erosion of organic matter rich topsoil during intense rainfall events, or more slowly through lateral subsoil movement of nitrate-N in soil water.

The main upwards N loss pathways consist of gaseous losses through either ammonia volatilisation or denitrification of nitrate.

In 2012–15, six experiments with isotope-labelled (15N) urea fertiliser were conducted in northern NSW and a further 11 in southern Queensland, all focussed on measuring the fate of applied N fertiliser in summer sorghum. The use of 15N allowed researchers to trace the fate of urea-N applied to the soil from sowing through to harvest. [32]

Between 56 and 100% of the applied N was found in the soil and plant at harvest, with in-season rainfall (both timing and amount) and soil C and N status having a major impact on the seasonal loss potential.

Avoiding unnecessarily high N rates, delaying or splitting N fertiliser so that peak N availability coincides with peak crop N demand, and relying on residual N from legume rotations all significantly reduced gaseous N losses from dryland sorghum, although the effectiveness of any management strategy varied with seasonal conditions.

Nitrification inhibitor-coated urea significantly reduced nitrous oxide emissions in all studies, but did not improve grain yields enough to justify the additional cost on an agronomic basis.

30 M Gardner *et al.* (2013) Agronomic and economic responses of sorghum to nitrogen nutrition. GRDC Update Papers 18 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Agronomic-and-economic-responses-of-sorghum-to-nitrogen-nutrition

31 M Bell, G Schwenke, D Lester (2016) Understanding and managing N loss pathways, GRDC Update Papers 22 June 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/06/Understanding-and-managing-N-loss-pathways

32 M Bell, G Schwenke, D Lester (2016) Understanding and managing N loss pathways, GRDC Update Papers 22 June 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/06/Understanding-and-managing-N-loss-pathways

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans?highlight=sorghum

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

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

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/146690/err-20-Farming-Systems-in-the-Northern-Cropping-Region-of-NSW--An-Economic-Analysis-Region-of-NSW-An-Economic-Analysis.pdf

http://espace.library.uq.edu.au/view/UQ:159371

http://livestocklibrary.com.au/handle/1234/21419

MORE INFORMATION

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

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

Depending on the season, delaying/splitting N applications gave either no yield benefit (dry season) or a significantly greater yield (good in-crop rainfall). Much of the unused N after a dry season remained in the soil and, provided loss events were not experienced during the fallow, significantly benefited the following crop.

1.9.4 Short-fallow options

In northern NSW–southern Queensland, chickpeas are the most popular double-crop option after sorghum. Chickpeas are relatively tolerant of atrazine residues and are slower to use stored soil water. This double-crop system with chickpeas also has environmental benefits by enabling chickpeas to be grown on sloping soils without the same degree of soil erosion during the following summer fallow period.

Mungbeans may be included in the rotation as a double-crop option as a short fallow (6 months) following sorghum. They can also be grown immediately following winter cereal harvest, or after a long fallow (18 months) from a winter cereal crop. When planting into sorghum stubble, Atrazine residues are most likely to be a concern. The rate used will determine the plant-back safety, with 9 months being adequate at lower rates.

Like mungbeans, soybeans are a short-duration, summer-growing grain crop. Soybeans also commence flowering in ~45 days, but are slower to mature than mungbeans, taking 130–140 days to harvest. As a summer grain legume, soybeans are well suited to growing in rotation with a range of crops including sorghum, winter cereals, canola, cotton and maize.

Most soil types in central west NSW are suited to soybean growing. Like mungbeans, soybeans do not tolerate waterlogging. Warm, moist seedbeds with good drainage provide the best start for soybean establishment. Where furrow irrigation is used, high hills are required to minimise waterlogging. Crusting soils can also create problems for emerging soybean plants, because of epigeal germination (i.e. the soybean leaves must be able to push their way through to the soil surface). Removing stubble from the plant line in dryland, no-till situations will also assist establishment. [33]

1.10 Nematode status of the paddock

In the northern grains region, the predominant root-lesion nematode (RLN), *Pratylenchus thornei,* costs the wheat industry A$38 million annually. [34] Including the secondary species, *P. neglectus*, RLN is found in three-quarters of fields tested.

Resistance and susceptibility of crops can differ for each RLN species, and sorghum is resistant to *P. thornei* but susceptible to *P. neglectus*. [35]

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

33 L Jenkins (2012) Summer crop options for the central west—mungbeans & soybeans. GRDC Update Papers 10 April 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Summer-crop-options-for-the-central-west-mungbeans-soybeans?highlight=sorghum

34 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

35 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

a paddock is free of these nematodes is valuable information because steps may be taken to avoid future contamination of that field. [36]

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

MORE INFORMATION

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

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

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% 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 numbers 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 chickpeas, 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 QDAF planting guides. Note that crops and varieties have different levels of tolerance and resistance to *Pratylenchus thornei* and *P. neglectus*.

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

MORE INFORMATION

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

Summer crops have an important role in management of RLN. Research shows when *P. thornei* is present in high numbers, two or more resistant crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops. [37]

For more information on nematode management, see GrowNotes Sorghum 8. Nematodes.

1.11 Insect status of paddock

1.11.1 Insect sampling of soil

MORE INFORMATION

Melina Miles QDAF describes germinating seed bait technique for checking insect populations prior to sowing. GRDC Podcast: 104 Thrips worrying early summer crops

It is important to monitor and control soil-dwelling insects such as wireworms at sowing. [38]

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

Soil insects include:

- cockroaches
- crickets
- earwigs

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

37 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

38 NSW DPI (2005) Grain sorghum. Agfact P3.3.5. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/146355/grain-sorghum.pdf

- 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 from 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 because of 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.

Control measures against soil insects 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.
4. Spade sampling is laborious, time-consuming and difficult in heavy clay or wet soils.

Germinating-seed bait technique

Immediately following planting rain:

1. Soak insecticide-free crop seed in water for at least 2 h to initiate germination.
2. Bury a dessertspoon of the seed under 1 cm of soil at each corner of a 5 m by 5 m square at five widely spaced sites per 100 ha.
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. [39]

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/

39 QDAF (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