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GRDC™ GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 1

PLANNING AND PADDOCK PREPARATION

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Planning/Paddock preparation

Chickpea crops should be separated from the previous year's crop by at least 500 m and up to 1 km in areas where old stubble is prone to movement (i.e. downslope and on flood plains). This helps to reduce the spread of the foliar and stubble-borne disease, Ascochyta blight. Avoid paddocks with high weed burdens, as chickpeas provide poor competition for weeds.

Prior to sowing, growers are advised to discuss with their agronomists their herbicide use over the previous 1–2 years and any potential residue problems. They should also understand crop management and harvest problems created by unlevelled paddocks and paddock obstacles.

Prior to planting, review soil tests and records, paying particular attention to the following soil characteristics:

- pH 5.2–8.0
- soil type—loams to self-mulching clays
- sodicity—avoid exchangeable sodium percentage (ESP) levels ≥3
- salinity, chloride—avoid electrical conductivity (EC) levels >1.5 dS/m
- potential waterlogging problems
- amount of stored soil moisture and received rainfall, noting their potential impact on herbicide residues [1]

Chickpeas established by direct drilling into standing cereal stubble reliably yield 10% higher than when using other planting techniques (Figure 1). [2]

1 G Cumming (2014) Chickpea varieties selecting horses for courses. GRDC Update Papers 5 March 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Chickpea-varieties-selecting-horses-for-courses

2 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

More information

NSW DPI Winter crop variety sowing guide

Figure 1: Better chickpea yields are achieved by sowing into cereal stubble. (Photo: Gordon Cumming, Pulse Breeding Australia.)

1.1 Chickpea requirements

Chickpeas prefer well-drained loam to clay soils with a pH in the range 6–8. They will not grow in light acid soils. Areas prone to waterlogging should be avoided. This advice also applies to stony ground, because the plants need to be harvested close to the ground.

Chickpea are susceptible to hostile subsoils, with boron toxicity, sodicity and salinity causing patchiness in affected paddocks. Exchangeable aluminium tolerance in chickpea is nil. Tolerance to sodicity in the root-zone (to 90 cm) is <1% ESP on the surface and <3% ESP in subsoil (Table 1).

Broadleaf weeds and herbicide-resistant grasses can cause major problems, and a careful management strategy must be prepared well in advance. It may be possible to control the weeds in the year prior to cropping; however, paddocks with specific weeds that cannot be controlled by herbicides should be avoided.

Foliar sprays of zinc and manganese may be needed where deficiencies of these micronutrients are a known problem, in particular on high-pH soil types. [3]

[3] Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Table 1: Pulse crop soil requirements

Crop	Soil type	Soil pH (CaCl2)	Exchangeable aluminium (%)	Drainage tolerance and rating (1–5)	Sodicity in root-zone (90 cm) exchangeable sodium percentage
Lupin, narrow leaf	Sandy loams	4.2–6.0	20% tolerant	Sensitive (2)	<1 surface <3 subsoil
Lupin, albus	Sandy loams, clay loams	4.6–7.0	Up to 8%	Very sensitive (1)	<1 surface <3 subsoil
Field pea	Sandy loams, clays	4.6–8.0	Up to 5–10%	Tolerant (3)	<1 surface <3 subsoil
Chickpea	Loams, self-mulching clay loams	5.2–8.0	Nil	Very sensitive (1)	<1 surface <3 subsoil
Faba bean	Loams, clay loams	5.4–8.0	Nil	Very tolerant (4)	<1 surface <3 subsoil
Canola	Loams, clay loams	4.8–8.0	0–5%	Tolerant (3)	<1 surface <3 subsoil
Lucerne	Loams, clay loams	5.0–8.0	Nil	Sensitive–tolerant (1–3)	<1 surface <3 subsoil

Source: G. Mullen (2004) Central NSW soils, NSW DPI.

More information

NSW DPI Paddock selection after drought

QDAF (2015). Planting chickpeas.

1.2 Paddock selection

Uniformity of soil type, paddock topography, and surface condition of the paddock are all important criteria in assessing whether country is suitable for chickpea production.

1.2.1 Avoid major variations in soil types

Crop maturity can be significantly affected by moisture supply during the growing season. Any major changes in soil type and moisture storage capacity across a paddock can lead to uneven crop maturity, delayed harvest, increased risk of weather damage, and/or high harvest losses due to cracking and splits. Uneven crop development also complicates timing of insecticide sprays, timing of desiccation, and management of Ascochyta blight.

Selecting a paddock with minimal variation in soil type will often help to provide even maturity and ripening of the crop. This will enable harvesting at the earliest possible time, increase quality, and minimise harvest losses. The overall result is usually a more profitable crop.

1.2.2 Avoid deep gilgai or heavily contoured country

Contours and undulating country ('melon holes' or 'crab holes') present two problems:

- Uneven crop maturity due to variation in soil water supply. Melon-holes usually store more water than the mounds, and the crop in wetter areas will often continue to flower and pod when the rest of the crop is already drying down. Similarly, contour banks retain more moisture after rain, and prolong crop maturity relative to the rest of the crop late in the crop.
- High harvest losses and increased risk of dirt contamination in the header sample. Many dryland chickpea crops require the header front to be set close to ground level, and even small variations in paddock topography can lead to large variations in cutting height across the header front, and a significant increase in harvest losses.

Contamination of the harvested sample with dirt and clods is difficult to avoid in undulating, gilgai country, and can cause a significant increase in grading losses and costs.

Foreign material must not exceed 3% by weight, of which no more than 0.3% must be unmillable material (soil, stones and non-vegetable matter). If a farmer delivers chickpeas that do not meet this export standard, they will need to be graded at a cost of $15–25/t.

1.2.3 Problematic paddocks

Stones and sticks are a concern in poorly or recently cleared country. Harvest losses increase dramatically if the header front needs to be raised to avoid serious mechanical damage to the header. Small stones and wood fragments can also contaminate the seed sample and downgrade quality.

Cloddy or badly ridged paddocks are likely to cause contamination of the chickpea sample during harvest. Level the soil surface as much as possible, either during ground preparation or at sowing. A land-roller can be helpful after sowing, in cultivated situations, to level the soil surface and push clods of soil and small stones back down to level with the surface.

1.2.4 Bunching and clumping of stubble

Stubble bunching or clumping can occur when sowing into retained stubble as a result of blockages during sowing. These mounds of stubble are often picked up in the header front, causing mechanical blockages and contamination of the sample if they contain excessive amounts of soil.

Management options for dealing with stubble clumping include:

- use of a no-till (disc) seeder or other seeder capable of handling heavy stubble
- modification of existing air-seeders (tine shape and lifting some tines)
- sowing before soil and stubble becomes too wet
- use of rotary harrows to spread and level stubble and sow between old plant rows aiming to leave stubble standing

Standing stubble can be slashed or burnt if sowing equipment with good trash flow is not available. [4]

1.3 Benefits of chickpeas as a rotation crop

1.3.1 Chickpeas preceding wheat

The benefits are:

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

Risks:

- Poor weed competition. There is potential for build-up of Group A herbicide resistant wild oats, phalaris, and annual ryegrass, as there are few options registered for chickpeas. There is also potential for an increase in seed-bank population of problematic and hard-to-control weeds such as wireweed and climbing buckwheat.
- Nematodes are a major drawback to planting chickpeas before wheat. Recent field data show consistent differences in *Pratylenchus thornei* resistance between commercial chickpea varieties. Figure 2 shows a summary of performance of key chickpea varieties in eight trials sampled by Department of Agriculture, Fisheries and Forestry Queensland (DAFF), New South Wales Department of Primary Industries or Northern Grower Alliance (NGA).

More information

GRDC Update paper, 2013: Managing root lesion nematode: how important are crop and variety choice

A Verrell (2016), Integrated management of crown rot in a chickpea – wheat sequence

[4] Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

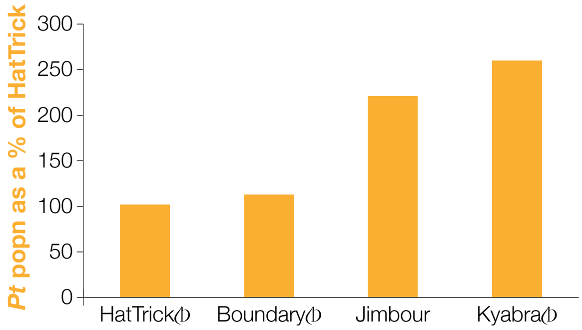

Figure 2: All varieties evaluated in 9 trials 2011-13 (DAFF, NSW DPI, NVT and NGA)

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.

Chickpeas also provide 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 can offset the potential for small yield loss.
- Band spraying of wide rows reduces the amount of pesticide in the environment.
- Shielded spraying between wide rows allows rotation of chemistry for weed control.
- Ability to deep-sow provides the opportunity to plant on time most years.

More information

https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

Pulse Australia (2016). Chickpea Production: Northern Region

NSW DPI (2015). Nitrogen benefits of chickpea and faba bean

Depending on the scale of the farm operation, other winter rotation crops and summer crops could be integrated into a rotation that contains chickpeas. Several long-term rotation trials have quantified the benefits of chickpeas 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 influencing the final yield outcome. In most situations, chickpeas 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 (see Table 2). [5]

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. [6]

[5] M Lucy, D McCaffery, J Slatter (2006) Northern grain production—a farming systems approach. 2nd edn. Pulse Australia Ltd, http://www.pulseaus.com.au/storage/app/media/crops/2006_Pulses-northern-grain-farming-systems.pdf

[6] 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 2: 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).

Chickpeas provide many benefits in northern cropping rotations, including the ability to fix atmospheric nitrogen (N2), resulting in more soil N for following cereal crops. The amount of nitrogen fixed is determined by how well the pulse crop grows and the level of nitrate in the soil at planting. Soil nitrate suppresses nodulation and nitrogen fixation. Thus, high soil nitrate means low nitrogen fixation.

The nitrate-N benefit from chickpeas over a range of grain yields is shown in Table 3.

For chickpeas growing in the low nitrate soil, the nitrate-N benefit is consistently positive, ranging between 27 kg and 43 kg nitrate-N/ha over the range of yields (1.0–3.5 t/ha). In the moderate nitrate soil, the nitrate-N benefit of chickpeas essentially disappears. The simple message to take from this is that chickpeas should be grown in low nitrate soils so that they can fix large amounts of nitrogen, add to the soil's nitrogen fertility (balance) and, importantly for short-term productivity, increase the amount of nitrate-N in the root zone. [7]

Table 3: Nitrate-N benefit from chickpea over a range of grain yields.

		Low soil nitrate at sowing (50 kg N/ha)			Mod soil nitrate at sowing (100 kg N/ha)		
Grain yield (t/ha)	Shoot dry matter (t/ha)	N fixed (kg/ha)	N balance (kg/ha)#	Nitrate-N benefit (kg/ha)	N fixed (kg/ha)	N balance (kg/ha)#	Nitrate-N benefit (kg/ha)
1.0	2.7	37	1	35	22	-14	16
1.5	3.9	72	18	28	50	-5	3
2.0	5.1	110	40	27	80	9	-5
2.5	6.2	152	62	30	115	25	-9
3.0	7.2	195	88	35	150	43	-10
3.5	8.2	240	115	43	188	63	-8

(Source: NSW DPI)

1.3.2 The pulse effect on cereal yields

Pulses and cereal crops are complementary in a cropping rotation. The means by which a crop affects following crops include well-recognised processes related to disease, weeds, rhizosphere microorganisms, herbicide residues, residual soil water and mineral N. They may also include two recently discovered processes. One is growth stimulation following hydrogen gas released into the soil by the legume–rhizobia symbiosis. The other is a drain on assimilates when the roots are strongly colonised by the hyphae of arbuscular mycorrhizal fungi (AMF) built up by a previous colonised host crop.

7 NSW DPI (2015), Nitrogen benefits of chickpea and faba bean. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/572661/nitrogen-benefits-of-chickpea-and-faba-beans.pdf

More information

[GRDC Ground Cover, 2013: Trials measure chickpea/wheat rotation profit]

[GRDC Ground Cover, 2013: Trials explore chickpea/wheat rotations]

Pulses fix their own N, leaving available N in the soil for the following cereal crop. Pulses also play a vital role in helping manage major cereal root diseases, particularly crown rot, by allowing more time for the cereal stubble to break down between host crops.

The combination of higher soil N and reduced root diseases is cumulative and can result in a dramatic increase in subsequent cereal yields. The amount of N fixed is determined by how well the pulse crop grows, reflecting the effectiveness of nodulation, seasonal conditions, crop management, and the level of nitrate in the soil at sowing. Soil nitrate suppresses nodulation and N fixation, hence high soil nitrate means low N fixation.

Crown rot

Crown rot (caused by *Fusarium pseudograminearum*) is a major constraint to winter cereal production in Australia. The disease effectively blocks the base of infected tillers, preventing water movement from the roots through the stems and producing prematurely ripened heads (whiteheads) that contain no grain or lightweight shrivelled seed. Crown rot is a stubble-borne pathogen and survives as mycelium (cottony growth) inside cereal and grass weed residues.

The initial starting levels of crown rot inoculum and the season in which break crops are grown will influence their effectiveness. Hence, rotations to non-host winter pulses, oilseeds or summer crops are the most important component of an integrated disease management system.

The effectiveness of a break crop in reducing yield loss to crown rot is a function of both inoculum survival (decomposition) and water-use pattern of the break crop.

Chickpeas tend to use less water during the season than canola and generally do not root as deeply. Cereal crops following chickpea may experience reduced moisture stress through this water saving, thus reducing the development of whiteheads in infected tillers.

Yield response in a following cereal crop as a result of the benefit of reducing crown rot is a function of a break crop's effect on inoculum survival, and soil water and N.

Yield responses from NSW DPI experiments are summarised in Figure 3, where wheat yield following break crops is compared with other disease-management options of a long fallow, and early (December) or late (May) burning of wheat stubble.

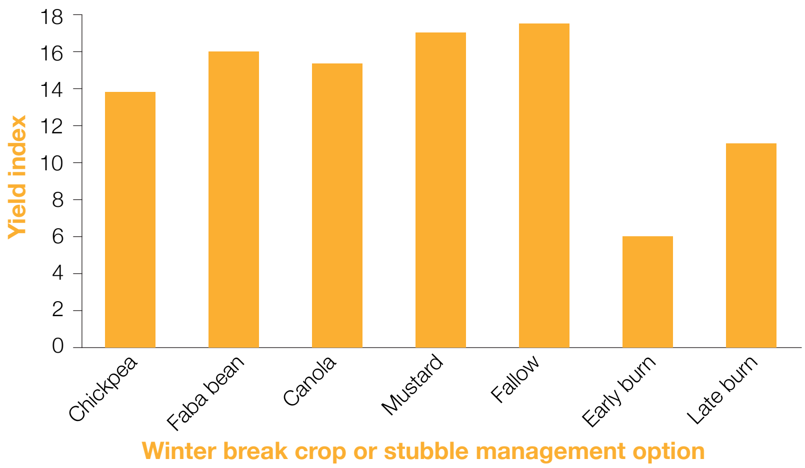

Figure 3: Yield index of wheat after various break crops of management options compared with continuous wheat. (Source: NSW DPI, 2006).

All winter and summer break-crop options provide a yield benefit in subsequent cereal crops as a direct result of reducing levels of crown rot. The selection of the appropriate break crop to suit individual situations will have the most economic benefit.

Quantifying yield increases after break crops

Yields of wheat grown after a broadleaf break crop generally exceed those of wheat grown after wheat or other cereals. The presumed reasons for the yield benefit vary between break crops. They include reduced root and foliar disease, increased supply of soil water and mineral N, reduced assimilate loss to mycorrhizae, and, after legumes, growth stimulation following hydrogen gas release.

Data used to evaluate the reasons for yield increase suggest that control of soil-borne disease, and residual N, after legumes are the largest benefits of break crops. [8]

1.4 Which rotation is best?

Determining the most suitable cereal–pulse–oilseed rotation requires careful planning. There are no set rules and it is best to plan a separate rotation for each cropping paddock.

The major aim should be to achieve sustainability and the highest possible overall profit, but to achieve this, the rotation must be flexible enough to cope with key management strategies such as maintaining soil fertility and structure, controlling crop diseases, and controlling weeds and their seed-set.

The same pulse should not be grown in succession, and extreme care must be taken if growing the same crop in the same paddock without a spell of at least 3 years. Successive cropping with the same pulse is likely to result in a rapid build-up of root and foliar diseases as well as weeds. Where possible, alternate the type of pulse crop being grown in a continuous rotation with cereals.

To minimise foliar diseases, it is important to recognise that a distance of at least 500 m is needed between the planned pulse crop and the stubble of that pulse (or others) from the previous year.

1.4.1 Nitrogen fixation

A pulse crop does not necessarily add large quantities of N to the soil. The amount of N fixed is determined by how well the pulse crop grows, reflecting the effectiveness of nodulation, seasonal conditions, crop management, and the level of nitrate in the soil at sowing. Soil nitrate suppresses nodulation and N fixation. Thus, high soil nitrate means low N fixation (Figure 4).

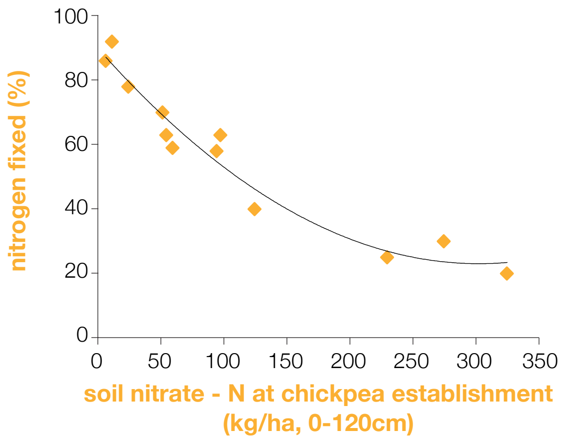

Figure 4: Effect of soil nitrate nitrogen on nitrogen fixation by chickpeas. (Source: J.A. Doughton et al 1993).

8 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

1.4.2 Nitrate-N benefit for following cereals

The nitrate-N benefit from chickpea over a range of grain yields has been calculated from trials in northern Australia (Herridge *et al*. 2003) and is shown in Table 4. The terminology is important to an understanding of N budgets for chickpea and faba bean:

- 'Total N fixed'—the N fixed in both aboveground (shoots) and belowground (roots and nodules) biomass. With chickpea, 50% of total crop N is below ground.
- 'Nitrogen balance'—the difference between N inputs to the pulse crop (N fixation + N applied) and N outputs (N harvested in grain or hay + N lost (volatilised) from the crop and soil).
- 'Nitrate-N benefit'—the extra nitrate-N available at sowing in soil that grew a pulse crop in the previous season, compared with soil that grew a cereal crop.
- 'Harvest index' (HI)—for different crops, the relationship between shoot dry matter and grain yield (i.e. HI) may vary according to season and management.

Table 4: Nitrate-N benefit from chickpea, over a range of grain yields (all values are kg/ha)

Grain yield (t/ha)	Shoot dry matter (t/ha)	Low soil nitrate at sowing (50 kg N/ha)			Mod soil nitrate at sowing (100 kg N/ha)		
		N fixed	N balance	Nitrate-N benefit	N fixed	N balance	Nitrate-N benefit
1.0	2.4	31	–3	16	13	–21	4
1.5	3.6	74	22	28	47	–5	13
2.0	4.8	120	49	44	84	12	24
2.5	6.0	157	66	48	111	21	38
3.0	7.1	198	88	52	141	31	52
3.5	8.3	231	102	57	164	35	64
4.0	9.6	264	116	61	188	39	69

Source: Grain Legume Handbook (2008).

By understanding the development and measurement of crop biomass and the factors that influence HI, better N and rotation management decisions can be made.

1.4.3 Availability of nitrogen

One of the tangible benefits of a pulse crop is the rapid breakdown of the N-rich organic matter remaining after the crop has been grown.

Most of this organic N is readily available to the following crop and is one of the reasons why cereal yields are often high following a pulse crop.

1.4.4 Weeds

A range of effective herbicides is available to control grasses in pulse crops. It is now possible to control wild oats and ryegrass.

However, control of herbicide-resistant weeds such as wild oats and annual ryegrass is now a major issue, and appropriate planning and management are needed.

Some of the weeds are not effectively controlled in the following cereal crop, but by controlling them in the pulse phase of a rotation and preventing them from setting seed, they can be virtually eliminated from the following cereal crop.

Pulses, particularly chickpeas, are poor weed competitors. Unless attention is paid to effective control measures, weeds are likely to build up, reducing yields and seriously affecting future crops.

Crop rotation is a key strategy in managing herbicide resistance, allowing for the use of herbicides with different modes of action from those used in cereal crops.

Many of the broadleaf weeds can be difficult to control and can cause substantial yield loss and grain contamination. Good knowledge of likely weed problems is needed, because most broadleaf herbicides are applied before sowing or before crop emergence. [9]

1.5 Disadvantages of chickpeas as a rotation crop

Chickpeas are also susceptible to Ascochyta blight, and as a high priority, new chickpea crops should be grown at least 500 m from chickpea stubble to avoid infection. [10]

Growers should aim for a break of at least 4 years between chickpea crops in each paddock. Chickpeas are intolerant to root-lesion nematodes, and some chickpea varieties lose up to 20% yield when nematode populations are high. [11]

Where profile N is high there may be little additional N fixed by chickpeas.

Chickpeas are poor competitors with weeds. [12]

Chickpeas are also susceptible to Phytophthora root rot, so avoid sowing chickpeas into paddocks with a history of any level of the disease, paddocks with a history of lucerne or medics, and paddocks prone to waterlogging and/or flooding.

More information

Australian Pesticides and Veterinary Medicines Authority (APVMA)

GRDC Update Paper, 2014: Weeds and resistance considerations for awnless barnyard grass, chloris and fleabane (NGA)

1.6 Fallow weed control

Chickpeas are slow to emerge and initially grow slowly. They are notoriously poor competitors with weeds. Even moderate weed infestation can result in severe yield losses and harvesting problems. The best form of weed control is rotation and careful selection of paddocks largely free from winter weeds, for example, double-cropped from sorghum or cotton, or areas with a sequence of clean winter fallows.

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. Knowledge of your paddock and early control of weeds are important for good control of fallow weeds. Information is included for the most common of the problem weeds; however, for advice on individual paddocks you should contact your agronomist.

More information

GRDC Fact Sheet, 2014: Summer fallow spraying

C McMaster, N Graham, J Kirkegaard, J Hunt, I Menz (2015). "Buying a spring" – the water and nitrogen cost of poor fallow weed control.

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 where soil water is present that would support continued weed growth. [13]

[9] Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

[10] W Hawthorne, J Davidson, L McMurray (2012) Chickpea disease management strategy. Pulse Australia Southern Pulse Bulletin #8, http://pulseaus.com.au/storage/app/media/crops/2012_SPB-Chickpea-disease-management.pdf

[11] DAFF (2009) Management of root-lesion nematodes in the northern grain region. Department of Agriculture Fisheries and Forestry, http://www.daf.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

[12] W Hawthorne, J Davidson, L McMurray (2012) Chickpea disease management strategy. Pulse Australia Southern Pulse Bulletin #8, http://pulseaus.com.au/storage/app/media/crops/2012_SPB-Chickpea-disease-management.pdf

[13] GRDC (2012) Make summer weed control a priority—Southern region. Summer Fallow Management, GRDC Fact Sheet January 2012, https://www.grdc.com.au/~/media/8F16BE33A0DC4460B17317AA266F3FF4.pdf

The NGA is trialing methods to control summer grasses. Key findings so far 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 key to 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.

More information

GRDC Fact Sheet,2012: Effective Double Knock Herbicide Applications Northern Region

Australian Herbicide Resistance Initiative (2015). Knock knock.

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. [14]

Consider the species present, interval timing and water rate.

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.

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

[14] 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%202.2doubleknock.pdf

Awnless barnyard grass

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

Awnless barnyard grass (Figure 5) has been a major summer grass problem for many years. It is a difficult weed to manage for at least three main reasons:

1. It has multiple emergence flushes (cohorts) each season.
2. It is easily moisture-stressed, leading to inconsistent knockdown control.
3. Glyphosate-resistant populations are 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, such as Weedseeker or WeedIt.
- 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®), and these 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 the 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 (e.g. mungbeans). Even on glyphosate-resistant ABYG, a glyphosate followed by paraquat double-knock is an effective tool. 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 about 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: DAFF, Qld.)

There are three main species of fleabane in Australia: *Conyza bonariensis* (flaxleaf fleabane, Figure 6), *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. [15]

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 levels of surface soil moisture 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 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

[Australian Glyphosate Sustainability Working Group (AGSWG): Australian glyphosate resistance register]

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)

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. There are no registered knockdown options in chickpeas.

More information

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

[15] 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 nearly always recover.

Timing of the second application in fleabane is generally aimed at about 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 about 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 (Figure 7) has emerged as an important weed-management issue in southern Queensland and northern NSW since about 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

Whereas a glyphosate followed by paraquat double-knock is an effective strategy on

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

While FTR has been a grass weed threat coming from Queensland and heading south, windmill grass (Figure 8) is more of a problem in central NSW and 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 challenges to management.

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-western 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, no products are 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 about 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 or less. Good control can often be obtained up to 21 days after the initial application. [16]

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

1.7 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 persistence. 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 Table 4 where known. The rate of decay is influenced by soil pH and moisture levels.

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. [17]

16 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

17 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 broadacre trials and paddock experiences [18]

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

1.7.1 Herbicide residues in soil

Residues from herbicides used in the current or previous crop could impact on subsequent crop choice in rotations. Crop damage could occur if this is ignored, particularly where rainfall has been minimal.

Pulse and other crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each crop type. Herbicide choice in cereal and oilseed crops may have to accommodate the planning of a pulse crop next in the rotation sequence. For example, it could be 10 months before a chickpea crop can be grown after use of an imidazolinone ('imi') herbicide, and likewise over 24 months after chlorsulfuron has been applied on high pH soils. [19]

[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

[19] Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

1.8 Understanding soils and pulse crop constraints

If poor crop growth and yield are occurring in a cropping paddock, or patches in it, despite good rainfall and soil moisture, a determination of what is constraining growth is needed, whatever the crop type (Figure 9).

Understanding growth constraints will influence crop choice or its management. Constraints may be soil related or biological (e.g. disease, an insect pest, or a nematode). Some guidelines are provided in Table 6 and Table 7 below to assist in testing and diagnosis.

Figure 9: Aerial shot of chickpea crops near Garah in 2012 showing wide-scale crop loss due to sodic/saline conditions.

Table 6: Indicative signs and likely causes of constraints to plant growth

Likely constraint	Indicative signs of a constraint	Possible solution
Biological	Roots may show dark lesions, knotting or discoloration (e.g. honey or brown coloured)	Identify the problem. Use crop rotations and farm hygiene and grow more resistant crops or varieties. Use fungicide or insecticide seed treatment, appropriate disease or pest control. Encourage the build-up of beneficial organisms through supplying organic substrate (e.g. stubble retention). Use direct drilling or no-till
Nutrient deficiency	Leaves or stems show characteristic symptoms of nutrient imbalance	Identify the nutrient disorder (soil or plant test). Apply appropriate fertiliser as granular, liquid injection or foliar application. Improve agronomy practices to build a healthier soil
Soil surface sodicity	Soil surface shows waterlogging, hard setting or crusting. Water ponds for several days after rain	Applying gypsum can improve soil surface sodicity by flocculating soil and so improving infiltration and exchange of sodium for calcium
Physical	Roots are deformed or may grow at a right angle. Rooting depth is restricted by presence of stones or rock, by a dense clay layer, hardpan, a plough layer or traffic compaction	Deep ripping may benefit some hardpans or compacted layers. Some ameliorant may need to be incorporated at the same time (e.g. organic matter, gypsum, lime). Controlled traffic will be needed afterwards. Growing plants with a taproot that is deep rooting can help
Chemical	There is an absence of fresh roots in the rooting zone (e.g. top 1 m of soil). The subsoil remains wet after a dry finish	Salinity: avoid sensitive crops such as chickpea and lentil, and grow more tolerant crops and varieties. If subsoil drainage is improved, then this can help to leach salts from the upper soil layers Acidity: use lime to as an ameliorant on acidic soils Sodicity: apply gypsum Alkalinity: elemental sulfur can help acidify highly alkaline soils, but large quantities will be required on heavy clay soils
Subsoil sodicity	Subsoil is lacking drainage. Structure of subsoil is coarse or dense	Sodicity: apply high rates of gypsum, but incorporation is needed, otherwise adequate rainfall and time are needed for gypsum to be effective in subsoils

Source: Grain Legume Handbook (2008).

Table 7: Testing and decision process to follow in determining which soil constraints apply

Electrical conductivity (EC, 1:5 water) (dS/m) Check soil for EC in surface and subsoil					
Low EC <0.3 dS/m in top 10 cm			High EC >0.3 dS/m in top 10 cm		
Low EC <0.7 dS/m in subsoil			High EC >0.7 dS/m in subsoil		
Plant growth is not affected by salinity:			Plant growth is affected by salinity:		
Check soil for exchangeable sodium percentage (ESP) and/or dispersion			**Check soil for sodium and chloride concentration**		
No dispersion (ESP <6)		Dispersion (ESP >6)	Cl >300 mg/kg in top 10 cm soil Cl >600 mg/kg in subsoil	Cl <300 mg/kg in top 10 cm soil Cl <600 mg/kg in subsoil	
Check soil pH (1:5 soil:water)				**Check for gypsum crystals and sulfur concentration**	
pH <5.5	pH >8.0			S >100 mg/kg	S <100 mg/kg
Acidity constraint	**Alkalinity constraint**	**Sodicity constraint**	**Osmotic effect due to high salt and Na/Cl toxicity,**	**High EC due to gypsum; no constraint to crop growth**	**No gypsum; other salts are causing the problem**

Source: Qld Natural Resources and Water Bulletin.

1.8.1 Chemical constraints

Soil pH can affect plant growth and nutrient availability.

Acid soils

Acid soils can significantly reduce production and profitability before paddock symptoms are noticed.

Danger levels for crops are when soil pH is <5.5 (in CaCl2) or 6.3 (in water). Monitor changes in soil pH by regular soil testing. If severe acidity is allowed to develop, then irreversible soil damage can occur. Prevention is better than cure, so apply lime regularly in vulnerable soils. The most effective liming sources have a high neutralising value and have a high proportion of material with particle size <0.25 mm. More lime is required to raise pH in clays than in sands. Liming can induce manganese deficiency where soil manganese levels are marginal.

Low soil pH often leads to poor or ineffective nodulation in pulses because acid soil conditions affect rhizobial initial numbers and multiplication. Field peas, faba beans, lentil and chickpea are vulnerable, as are vetches. Lupins are an exception because their rhizobia (Group G) are acid-tolerant.

Granular inoculums seem to provide greater protection to rhizobia in acid soil conditions.

Alkaline soils

In alkaline soils, the abundance of carbonates and bicarbonates can reduce crop growth and induce nutrient deficiencies. Presence of free lime has a major impact on lupin growth, inducing iron and manganese deficiency, which cannot be corrected by foliar sprays of those nutrients.

More information

http://www.grdc.com.au/uploads/documents/dnr00004.pdf

1.8.2 Sodic soils

Chickpeas are classified among the most sensitive of all field crops to sodic soil conditions (Table 8).

Soils high in sodium are structurally unstable, with clay particles dispersing when wet. This subsequently blocks soil pores, reduces water infiltration and aeration, and retards root growth. On drying, a sodic soil becomes dense and forms a hard surface crust up to 10 mm thick. This can also restrict seedling emergence.

Some indicators of surface sodicity include:

- soils prone to crusting and sealing up
- ongoing problems with poor plant establishment
- presence of scalded areas in adjoining pasture

Exchangeable sodium percentage is the measure for sodicity:

- ESP <3: non-sodic soils
- ESP 3–14: sodic soil
- ESP <15: strongly sodic

Soils that are sodic in the topsoil have the greatest impact on crop performance (see Figure 10 for effect of ESP on chickpea yield). Sodic layers deeper in the soil profile are not as great a concern but can still affect yields by restricting root development and water extraction from depth.

The net effect of severely restricted root growth in chickpeas is usually the early onset of drought stress.

It is unlikely that soil sodic layers deeper than 90 cm will have significant impact on chickpea yields.

Table 8: Relative tolerance of crops to sodicity (high exchangeable sodium percentage)

Tolerant	Semi-tolerant	Sensitive
Rice	Barley	Maize
	Wheat	Cowpeas
	Cotton	Peanuts
	Sorghum	Mungbeans
		Lentils
		Sunflower
		Guar
		Chickpea

Source: Abrol (1973).

Bob Brinsmead (formerly Qld Department of Primary Industries and Fisheries) confirmed soil sodicity as the cause of plant death and low yields on certain brigalow soils in the Billa Billa and Talwood areas in 2000.

Crops were very patchy, with considerable stunting and eventual plant death under the very dry seasonal conditions. Areas that were less affected in the paddocks were yielding about 1 t/ha. Dieback appeared to be associated with the pattern of gilgai throughout the affected paddocks.

While there is no clear-cut association between topography and vegetation type with the occurrence of sodicity, the problem is more likely to occur in:

- brigalow and brigalow–belah land systems
- duplex red-brown earths
- poplar box on texture contrast soils
- ironbark/bulloak land systems

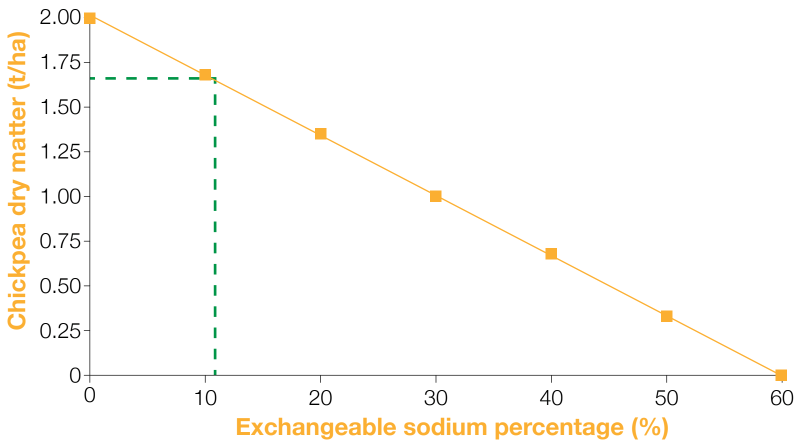

Figure 10: Impact of sodicity on chickpea dry matter production.

1.8.3 Salinity

Salinity is the presence of dissolved salts in soil or water. It causes iron toxicity in plants and impedes their ability to absorb water (see Figures 11 and 12 for typical salt effects).

Figure 11: Salt effects as seen on a soil of EC 11 ds/m.

Figure 12: Typical salt effects on chickpea leaves.

Chickpeas are extremely sensitive to salinity, and can have difficulty accessing water and nutrients from saline layers in the soil. This effectively limits water extraction from the subsoil and consequently yields.

As with sodicity, saline soil deeper than 90 cm down the profile is unlikely to impact on chickpea yields; the closer the surface, the greater the detrimental effect.

All current varieties of chickpea are considered highly sensitive to salinity. Levels of EC >1.5 dS/m will cause a yield reduction in chickpea, whereas wheat will tolerate EC up to 6 ds/m with no yield reduction (Table 9, Table 10).

Table 9: Crop tolerances to salinity (EC, mmhos/cm = dS/m = mS/cm)

Crop	Expected yield reduction:				
	0%	10%	25%	50%	100%
Barley	8.0	10.0	13.0	18.0	56.0
Cotton	7.7	9.6	13.0	1.70	54.0
Wheat	6.0	7.4	9.5	13.0	40.0
Sorghum	4.0	5.1	7.2	11.0	36.0
Peanut	3.2	3.5	4.1	4.9	13.0
Maize	1.7	2.5	3.8	5.9	20.0
Faba bean	1.6	2.6	4.2	6.8	24.0
Chickpea	*1.3*	*2.0*	*3.1*	*4.9*	*8.0*
Beans	1.0	1.5	2.3	3.6	13

Adapted from: Mass and Hoffman (1977) and Abrol (1973).

Table 10: Relative tolerance of plants to soil salinity, determined as electrical conductivity (EC) level at which yield is reduced by 50%

Note that actual numerical values of EC depend on soil texture and should be taken as a guide only. Salt tolerance is further reduced in seedlings

Soil salinity for 50% yield reduction (EC, dS/m)	Crop, pasture	Rating
12.0	Puccinella	Highly tolerant
7.0	Salt bush	
4.8	Tall wheat grass	
4.5	Barley	
4.1	Canola	Tolerant
4.0	Cereal rye	
3.25	Bread wheat	
3.1	Triticale	
2.6	Sorghum	
2.5	Safflower	Moderately tolerant
2.25	Lucerne	
1.85	Oats	
1.8	Vetch	
1.6	Faba bean	
1.25	Field pea, lupin	
<1.0	Lentil, chickpea	Sensitive

Source: PIRSA.

Nut grass (Figure 13) is often a good indicator of increased salt levels.

Figure 13: Nut grass growing in saline soil.

1.8.4 Soil chloride levels

Ferguson *et al.* (2006) found, when conducting the GRDC SIP08 Subsoil Constraints Project (NSW DPI) that soil chloride levels >600 mg/kg reduced root growth in crops such as chickpea, lentil and linseed. Soil analysis should be conducted to identify levels of chloride and at what depth it changes.

Thresholds for chloride concentration in soil and yield reductions differ between crops (Table 11 and Table 12).

Table 11: Thresholds for chloride concentration in soil (mg/kg)

Crop	10% yield reduction	50% yield reduction
Bread wheat	700	1500
Durum wheat	600	1200
Barley	800	1500
Canola	1200	1800
Chickpea	600	1000

Source: Qld Natural Resources and Water Bulletin.

Table 12: Soil constraint ratings for concentration of chloride (Cl) and sodium (Na)

Low	Medium	High
Surface soil (top 10 cm)		
<300 mg Cl/kg	300–600 mg Cl/kg	>600 mg Cl/kg
<200 mg Na/kg	200–500 mg Na/kg	>500 mg Na/kg
Subsoil (10 cm to 1 m)		
<600 mg Cl/kg	600–1200 mg Cl/kg	>1200 mg Cl/kg
<500 mg Na/kg	500–1000 mg Na/kg	>1000 mg Na/kg

Source: Qld Natural Resources and Water Bulletin.

Agronomic practices and crop choice

Agronomic practices and crop choices may have to vary for differing levels of soil salinity or sodicity constraints. Pulses such as chickpeas can be grown only where there are low salinity constraints.

Low constraints of Na and Cl (<600 mg Cl/kg, <500 mg Na/kg in top 1 m soil depth):

- Cereal–legume rotations are possible.
- Canola can be grown.
- Cereal diseases must be managed.
- Opportunity cropping to utilise available soil water can be tried.

Medium constraints of Na and Cl (600–1200 mg Cl/kg, 500–1000 mg Na/kg in top 1 m soil depth): tolerant crops should be grown (wheat, barley, canola):

- Consider tolerant crop varieties.
- The more tolerant of the pulses (vetch, faba bean possibly lupin and field pea) will likely suffer yield penalties if grown.
- Match inputs to realistic yields.
- Cereal diseases must be managed.
- Avoid growing salt-susceptible pulses (lentil, chickpea) or legumes, and durum wheat.
- Opportunity cropping to utilise available soil water can be tried, but options may be more limited.

High constraints of Na and Cl (>1200 mg Cl/kg, >1000 mg Na/kg in top 1 m soil depth):

- Avoid growing crops or grow tolerant cereals.
- Match inputs to realistic yields.
- Consider alternative land use to cropping (e.g. saline-tolerant forages, pastures).

1.8.5 Physical constraints

Physical constraints decrease oxygen and water movement in soils. Compacted soils and those with high physical strength (bulk density >1.5 g/cm3) impede root growth.

Subsoil compaction can be caused by heavy traffic or tillage on wet soils. Compacted layers may be visible, measured by high penetration resistance (> 2 MPa), or indicated by distorted root growth.

Deep ripping of soils and use of controlled traffic can help to overcome compaction, but in some soils, amelioration with organic matter, gypsum or lime, for example, may be required as well.

Chickpeas are particularly prone to hard pans and compacted soils, and suffer more from waterlogging if compaction layers exist.

1.8.6 Nutrient constraints

Crop management can affect nutrient deficiencies. Iron deficiency in pulses is more likely to occur in wheel tracks and compacted areas. Manganese deficiency is more likely in light, fluffy soil.

In pulses, cobalt and molybdenum are required for nodulation and N fixation, so deficiency of these trace elements can lead to poor nodulation.

Refer to Table 13 for nutrient constraints based on soil pH.

Table 13: Soil classifications for pH (1:5 soil:water).

Increasing acidity							Increasing alkalinity
Acidic				Neutral	Alkaline		
3	4	5	6	7	8	9	10
Toxicity of : Aluminium (Al) Manganese (Mn) Iron (Fe)		**Ideal pH Range** for plant growth				Toxicity of : Sodium (Na) Boron (Bo) Bicarbonate (HCO3)	
Deficiency of: Magnesium (Mg) Calcium (Ca) Potassium (K) Phosphorus (P) Molybdenum (Mo)						Deficiency of: Fe Zinc (Zn) Mn Copper (Cu) P	

Biological constraints

Problems can occur when there is a lack of beneficial organisms such as earthworms and arbuscular mycorrhizae fungi (AMF) in soils. Their build-up can be encouraged by use of stubble retention and direct drilling or no tillage as well as appropriate crop rotations.

Monocultures of cereals can lead to a build-up of cereal diseases. [20]

1.9 Herbicide residues in soil

Pulse growers need to be aware of possible herbicide residues that may affect crop rotation choices or cause crop damage. Herbicide residue impacts are more pressing where rainfall has been minimal. After a dry season, herbicide residues from previous crops could influence choice of crop and rotations more than disease considerations. The opposite occurs after a wet year.

Weed burden in the new crop will depend on the seed set from last year and residual herbicide efficacy.

Pulse crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each pulse type.

Residues of sulfonylurea herbicides can persist in some soils. These residues can last for several years, especially in more alkaline soils and where there is little summer rainfall. The pulses emerge and grow normally for a few weeks, and then start to show signs of stress. Leaves become off-colour, roots may be clubbed, and plants stop growing and eventually die. Refer to the labels for recommendations on plant-back periods for pulses following use of any herbicides. Be especially wary under conditions of limited rainfall since herbicide application.

Picloram (e.g. Tordon® 75-D) residues from spot-spraying can stunt any pulse crop grown in that area. This damage is especially marked in faba beans, where plants are twisted and leaves are shrunken (Figures 14, 15). In more severe cases, bare areas are left in the crop where this herbicide had been used, in some cases more than 5 years ago. Although this damage is usually over a small area, correct identification of the problem avoids confusion and concern that it may be some other problem such as disease.

In wheat–chickpea rotations the use of fallow and in-crop residual herbicides such as Broadstrike®, Eclipse®, Flame® Grazon®DS, Lontrel® and metsulfuron (Ally®, Associate®, Lynx®) Harmony®M should be avoided, particularly during the summer fallow or weed-control period (after November).

[20] Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

The use of long-term residual sulfonylurea herbicides such as Monza®, chlorsulfuron (Glean®, Lusta®), and Logran® in wheat should be avoided when re-cropping to chickpeas.

Figure 14: Effect of Tordon® soil residues affecting faba bean. Note the stem distortion and severe leaf curl. (Source: Grain Legume Handbook (2008)).

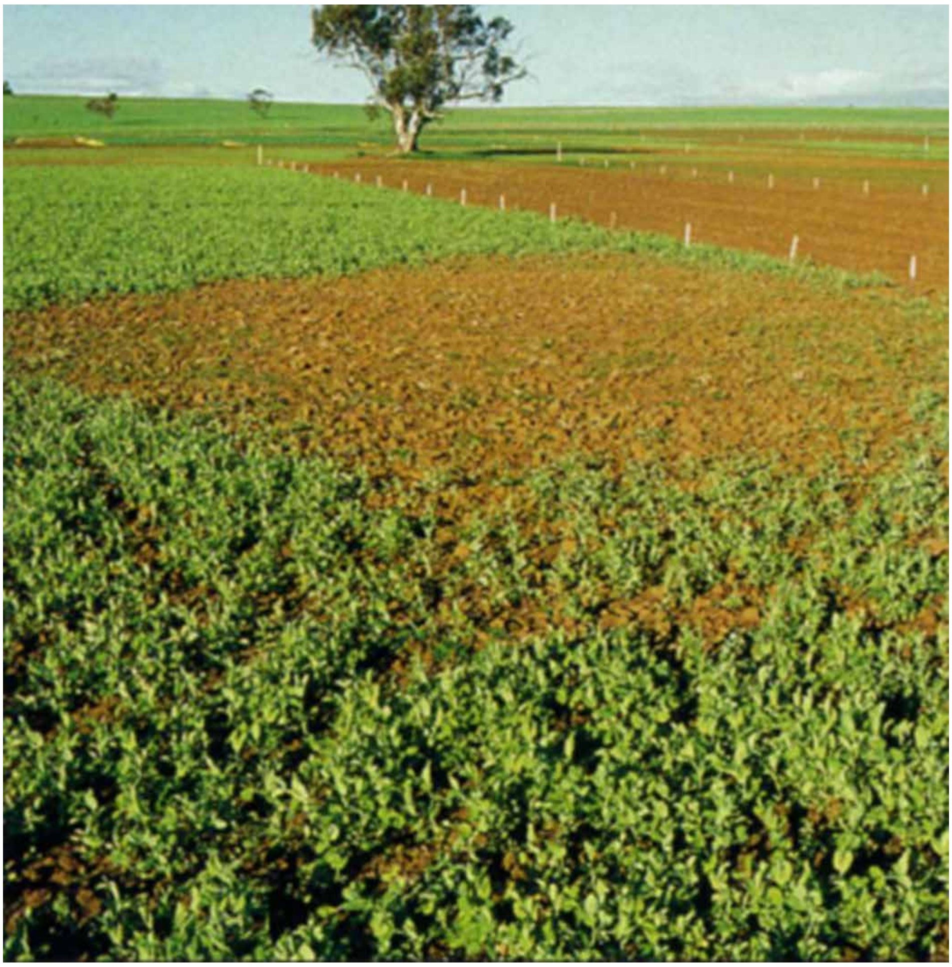

Figure 15: Tordon® spot-spray effect. Plants in the affected area are stunted. (Source: Grain Legume Handbook (2008).

1.9.1 Sulfonylurea residues, Group B

Sulfonylurea products include:

- metsulfuron (Ally®, Associate®, Lynx®)
- thifensulfuron plus metsulfuron (Harmony®M)
- sulfosulfuron (Monza®)
- chlorsulfuron (Glean®, Lusta®, Logran®)

Usually, Glean® or Logran® damage is not serious when these products are used as directed, although there is an increased risk of damage given:

- very dry or drought conditions
- highly alkaline (pH >8.5) soils
- excessive overlapping during application.

Sulfonylurea breakdown occurs by hydrolysis, and is favoured by warm, moist conditions in neutral to acid soils. Residues will tend to persist for longer periods under alkaline and/or dry conditions. Persistence of residues is greater for Glean® and Logran®, than for Ally® or Harmony®M.

Residues are root absorbed and translocated to the growing points; therefore, both roots and shoots are affected.

An application rate of 20 g Glean®/ha equates to an initial soil residue level of 10 parts per billion (ppb) in the top 10 cm soil.

Moderate residue levels

Plant emergence will be patchy, and the first true leaves elongated and narrow. Plants remain stunted, with severe chlorosis of the uppermost leaves (Figure 16).

Figure 16: Yellowing of new growth (left) and plant stunting (right). (Photo: A. Storrie)

Seedlings develop symptoms as the roots reach the sulfonylurea residue layer in the soil. This may occur in the early seedling stage on heavy clay soils, or slightly later on light sandy soils due to movement of residues down the soil profile. Symptoms are often more severe where there is soil compaction (e.g. in wheel tracks).

Symptoms include:

- spear-tipping of lateral roots (root pruning)
- yellowing of uppermost leaves, which can progress to older, lower leaves in severe cases.
- development of zinc-deficiency symptoms—narrow, cupped leaves
- stunted growth

Highly sensitive crops (in order of susceptibility)

- lentils
- chickpea (0.5 ppb)

Highly susceptible indicator weeds

- brassicas (turnip, mustard, radish)
- red pigweed, mintweed
- native jute
- parthenium weed
- paradoxa grass

Strategy

Avoid using Glean® or Logran® on very high pH soils (pH >8.5) if you intend growing chickpeas after wheat. Reassess risk if Glean® or Logran® has been used and drought conditions have been experienced during the wheat crop and in the subsequent fallow.

1.9.2 Imidazolinone (imi) residues, Group B

Imidazolinone products include:

- imazapic + imazapyr (Midas®, OnDuty®)
- imazamox + imazapyr (Intervix®)
- imazapic (Flame®)
- imazethapyr (Spinnaker®, various imazethapyrs)
- imazamox (Raptor®)

Figure 17: Spinnaker injury to the emerging new chickpea growth. (Photo: G. Cumming, Pulse Australia)

Imazethapyr (e.g. Spinnaker®) is registered for use in chickpeas in Victoria and South Australia, but can be damaging (Figure 17). Damage from residues of other 'imi' products should not be serious when used as directed, although there is an increased risk of damage where:

- plant-back periods or rainfall requirements are not adhered to;
- very dry or drought conditions have prevailed (often 150-200mm rainfall required);
- soils are highly alkaline (pH >8.5);
- extensive overlapping has occurred during application; or
- heavy rainfall after application concentrates treated soil in plant furrows.

Breakdown of imi products occurs by hydrolysis, and is favoured by warm, moist conditions in neutral to acid soils. Residues will tend to persist for longer under alkaline and/or dry conditions. Persistence of imi residues is greater for Intervix® and Midas® or OnDuty® than for Flame®.

Residues are root-absorbed and translocated to the growing points; therefore, both roots and shoots are affected.

Moderate residue levels

Plant emergence will be patchy, and the first true leaves elongated and narrow. Plants remain stunted, with severe chlorosis of the uppermost leaves.

Low residue levels

Seedlings develop symptoms as the roots hit the imi residue layer in the soil. This may occur in the early seedling stage on heavy clay soils, or slightly later on light sandy soils due to movement of residues down the soil profile. Symptoms are often more severe where there is soil compaction, such as in wheel tracks.

Symptoms include:

- spear-tipping of lateral roots (root pruning)
- yellowing of uppermost leaves, which can progress to older, lower leaves in severe cases
- development of zinc-deficiency symptoms—narrow, cupped leaves
- stunted growth

Highly sensitive crops (in order of susceptibility)

- lentil
- conventional canola
- safflower
- oats

Strategy

Avoid using imi products on very high pH soils (pH >8.5) if you intend growing chickpeas after a Clearfield® wheat or canola in an area with marginal rainfall. Reassess risk if imi products have been used and drought conditions have been experienced during the prior wheat, canola crop or fallow. Be wary of using imi products in short-term chemical fallows or for summer weed control where chickpeas are to be sown.

1.9.3 Triazine residues (atrazine), Group C

Chickpeas have some tolerance to very low rates of atrazine, but triazine carry-over from previous crops should be avoided (Figure 18). Products include: Gesaprim®, Nutrazine®, Farmozine®, various atrazines.

Atrazine significantly increases the frost sensitivity of the crop. Risk of damage increases where there are low levels of subsoil moisture (e.g. double-crop situations). Crops in this situation are largely surface-rooted and vulnerable to damage when there is herbicide recharge after each rainfall event.

Figure 18: Narrowing of the leaflets and multiple branching are signs of triazine residues (left). Similar distortion is seen in the roots (right). (Photo: G. Cumming, Pulse Australia)

All the evidence suggests that high rates of atrazine (>2.5 L atrazine/ha) should be avoided if considering double-cropping to chickpea after a summer forage or grain crop of sorghum or maize.

Atrazine breakdown is strongly influenced by soil type and climatic conditions. Rates of breakdown slow considerably under dry conditions, and can stop altogether under drought.

Atrazine is more persistent under the following conditions:

- alkaline soils (especially pH >8.0)
- increasing clay content (i.e. black earths)
- low soil temperatures
- low soil moisture levels.

Atrazine is root-absorbed and translocated up into the shoots, where it accumulates and inhibits photosynthesis. Plants usually emerge, but begin to show symptoms of stunting and chlorosis at 2–6 weeks of age. Atrazine initially accumulates in the tips and margins of the lower leaves. This results in bleaching and necrosis of the leaf margins. Plants are often stunted and plant growth is slow. Other Group C herbicides such as diuron and fluometuron cause similar symptoms, mainly on the older, lower leaves (e.g. when double-cropping chickpeas after cotton).

Highly susceptible indicator weeds

- mintweed (turnip, mustard, radish)
- brassicas
- black pigweed

Strategy

Avoid using heavier rates of atrazine (rate per ha depending on soil type) for summer grain or forage crops (e.g. sorghum, maize) if the intention is to follow with chickpeas in autumn–winter. Revise the strategy completely on highly alkaline black earths if high rates have been used in summer crops and dry conditions have been experienced.

1.9.4 Group I

Products include:

- 2,4-D products (amines, esters)
- dicamba (e.g. Cadence®)
- triclopyr (e.g. Garlon®)
- fluroxypyr (e.g. Starane®)

Residues of 2,4-D persist for a relatively short period, and they can be overlooked. Figure 19 depicts residual damage from 2,4-D. Table 14 shows the plant-back period for various rates of products, but the most important value is the minimal rainfall requirement prior to sowing. In 2006 there was significant 2,4-D damage in chickpeas resulting from an application of a 2,4-D product as a late fallow spray and/or knockdown spray prior to sowing. The re-cropping interval was not the cause; rather, the damage was due to not having received the minimal rainfall requirement of 15 mm before this period commenced.

Figure 19: Residual 2,4-D damage, showing narrowing and thickening of leaflets on younger growth. (Photo: J. Flemming, NSW DPI)

Table 14: Chickpea plant-back intervals and conditions after spikes in Group I knockdown herbicides

Active Ingredient	Products	Rates (/ha)	Period	Comments
2,4-D	2,4-D amine (625 g/L)	Up to 0.56 L	7 days	At least 15 mm of rain must fall prior to commencement of the plant-back period
	2,4-D ester (800 g/L)	Up to 0.35 L		
	Baton® (800 g/kg) (amine)	Up to 0.4 kg		
	2,4-D amine (625 g/L)	0.56–1.1 L		
	2,4-D ester (800 g/L)	0.35–0.7 L	14 days	
	Surpass® (300 g/L) (amine)	1.1–2.3 L		
	Baton® (800 g/kg) (amine)	0.4–0.9 kg		
	2,4-D amine (625 g/L)	1.1–17 L		
	2,4-D ester (800 g/L)	0.7–1.1 L	21 days	
	Surpass® (300 g/L) (amine)	2.3–3.4 L		
	Baton® (800 g/kg) (amine)	0.9–1.3 kg		
	Cadence®	140 g		
Dicamba (700 g/kg)	Cadence®	200 g	Not determined	When applied to dry soil, at least 15 mm of rainfall is required prior to commencement of the plant-back period
	Dicamba 500	400 g	21 days	
		200 mL	28 days	
Dicamba (500 g/L)	Dicamba 500	280 mL	Not determined	
	Garlon® 600, Invader® 600	560 mL	21 days	
	Safari® 600	Up to 160 mL	28 days	
Triclopyr (600 g/L)	Starane® 200, Flagship®	Up to 375 mL	7 days	
Fluroxypyr (200 g/L)			7 days	

1.9.5 Group I residual herbicides

Products include:

- clopyralid (Lontrel®)
- picloram (Tordon® 75-D, Tordon® 242, Grazon® DS)
- aminopyralid + fluroxypy (e.g. Hotshot®)

These products are used for in-crop or fallow weed control and can persist for long periods under dry conditions.

Lontrel® is used in canola, wheat, barley, triticale and oats, so care with a subsequent chickpea crop is required. It can persist on crop stubble for long periods and then it can become activated when leached into the soil following rainfall. Lontrel® is being used more often for residual control of fleabane.

Picloram residues are relatively stable in the soil, with residues fixed onto clay particles and remaining concentrated in the top 10–15 cm of soil. Residues are slowly broken down by microbial action, with decomposition slowing during the colder, winter months. Up to 25% of the applied dose can persist for up to 12 months, or longer under very dry conditions.

Some symptoms of low-level residue damage are not always readily visible in chickpeas, for example:

- retarded, slow growth
- thickening and callousing of the lower stem, usually just above ground level, which can be accompanied by cracking and splitting of the stem in more severe cases
- proliferation of short, lateral roots

There may also be some slight twisting and bending of the main stem. Higher rates of residue can also affect leaf shape, with a narrowing and thickening of leaflets. A severe reaction may cause cupping and stunting of leaflets.

Strategy

Avoid using Tordon® products in sorghum crops if you are considering the option of double-cropping back to chickpeas.

Avoid using Lontrel® or Grazon® DS in the fallow period prior to chickpeas. [21]

1.10 Soil moisture

1.10.1 Dryland

Desi chickpea varieties should be grown only in areas where the rainfall is >350 mm. Sowing is best carried out from early May to early June, with early sowing recommended for the lower rainfall areas.

Kabuli chickpea varieties are later maturing and should be grown only in areas where rainfall is >450 mm. [22]

Mild winter conditions can promote rapid vegetative growth, resulting in valuable soil moisture being used to grow high-biomass crops. [23]

With the possible exception of parts of central-western NSW on lighter soils, soil moisture storage during fallows and subsequent extraction and use during a crop season are at least as important as in-season rainfall for achieving a profitable yield result in most of the northern grains region.

The 2013 winter was an extreme example, when many crops in Queensland and north-eastern and north-western NSW were successfully grown on little or no effective in-crop rainfall. Although not always to that extent, subsoils and the root activity in them are key to success in most northern cropping seasons.

The frequency of such seasons obviously varies (winter *v.* summer, and between regions), and a research team led by Mike Bell, Queensland Alliance for Agriculture and Food Innovation (QAAFI), has used the climatic record from representative sites across the northern grains region to estimate the frequency of occurrence.

The researchers have also used APSIM (Agricultural Production Systems Simulator) to generate yield distributions for these seasons at high (240 mm) and low (120 mm) soil plant-available water storage capacity (PAWC) and different starting profile moisture contents (full, two-thirds full or one-third full). These simulations were used to estimate average yields of the four key crops (wheat, chickpea, mungbean and sorghum) in each season type, with these averages used to estimate the potential yields, from which losses due to phosphorus (P) deficiency can be calculated. These data are shown for wheat and chickpea, sown on a two-thirds full moisture profile in soils with a PAWC of 120 or 240 mm (Table 15).

More information

G Wockner, D Freebairn (2016), Commonly asked questions about soil water and soil management

D Freebairn (2016), Improving fallow efficiency

K Verburg, B Cocks, T Webster, J Whish (2016), Methods and tools to characterise soils for plant available water capacity (Coonabarabran)

D Freebairn (2016), SoilWaterApp – a new tool to measure and monitor soil water

21 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

22 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

23 K Moore *et al.* (2014) Phytophthora tolerance in chickpea varieties. GRDC Update Papers 4 March 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Phytophthora-tolerance-in-chickpea-varieties

Table 15: Frequency of occurrence of different season types (%), and the simulated crop yields (kg/ha) for wheat and chickpeas under those seasonal conditions for different production centres and soil types, with plant-available water capacity of 120 or 240 mm.

Location		Dry starts				Wet start, dry finish				No serious water stress			
		120 mm		240 mm		120 mm		240 mm		120 mm		240 mm	
		%	Yield	%	Yield	%	Yield	%	Yield	%	Yield	%	Yield
Emerald	Wheat	40	850	40	2530	38	1470	12	2370	22%	2780	48	3280
	Chickpea	28	540	28	1730	48	930	7	1470	23%	2140	65	2540
Dalby	Wheat	12	980	12	2260	69	1610	43	2890	19%	3860	45	5150
	Chickpea	7	660	7	1580	49	890	13	1650	44%	2330	80	2770
Goondiwindi	Wheat	10	1070	10	2520	66	1700	27	3040	24%	4430	63	4970
	Chickpea	5	720	5	2060	48	1060	6	1840	47	2390	90	2800
Gunnedah	Wheat	6	880	6	2560	56	2080	30	3340	39	4390	65	5490
	Chickpea	5	990	5	2140	36	1130	6	2930	59	2460	90	2930
Walgett	Wheat	11	775	11	2040	75	1670	43	2840	14	3840	46	4790
	Chickpea	9	630	9	1750	59	1030	16	1650	32	2130	75	2570
Condobolin	Wheat	6	780	6	2040	75	1940	51	3210	19	4640	44	5680
	Chickpea	4	590	4	1550	56	1110	11	1660	40	2240	85	2604

The data are derived from profiles assumed two-thirds full at sowing, with similar data available for sorghum and mungbeans from spring and summer sowing windows. These yields would be achieved if there were no nutrient limitations.

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Changing-nutrient-management-strategies-in-response-to-declining-background-fertility

Some important points about this analysis are:

- The frequency of Type 1 seasons (dry starts) is relatively low (5–10% of years), except in the Central Highlands of Queensland, where it ranges from 30 to 40% of years.
- There is a strong interaction between Type 2, late-stress seasons and soil type/PAWC, with the higher PAWC reducing the frequency of late-stress seasons by an average of 30% (wheat) to 40% (chickpeas). Average yields in those less frequent Type 2 seasons were still 800 (chickpeas) to 1200 (wheat) kg/ha higher in the high PAWC soils.
- Similar effects were evident in the summer crops (not shown), although the frequency of Type 1 seasons was much higher (average of 40% for sorghum and 21% for mungbean) than in winter crops. Higher PAWC reduced the average frequency of late-stress summer seasons by an average of 16% (sorghum) to 30% (mungbeans), with average yields in those late-stress seasons 1550 (sorghum) and 500 (mungbeans) kg/ha higher in the high PAWC soil. [24]

1.10.2 Irrigation

Soils must be well drained to reduce risk of waterlogging. Be aware of and monitor subsoil constraints that could limit yield potential.

It is important for growers and agronomists to base yield expectations on the total water supply available. This includes a combination of the amount of soil water in the profile, likely in-crop rainfall, and irrigation water supply. A general rule of thumb for chickpeas is 1 tonne grain per megalitre (ML) water supply (per ha).

Pre-sowing irrigation may be optional, depending on stored soil moisture following summer rainfall. Timing of the first in-crop irrigation is critical and must be pre-flowering, when PAW reaches 30–40% depletion. Sufficient moisture must be supplied to cover the flowering period. However, waterlogging an already stressed crop at flowering can cause severe yield loss or actual plant death (Figure 20). It is imperative to get the water on and off the paddock as quickly as possible when irrigating chickpeas.

[24] M Bell *et al.* (2014) Changing nutrient management strategies in response to declining background fertility. GRDC Update Papers 4 March 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Changing-nutrient-management-strategies-in-response-to-declining-background-fertility

Figure 20: An aerial shot of crops west of Moree, NSW, in 2012 shows waterlogging that caused plant deaths.

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/176053/North-Irrig-surface-chickpeas-2012.pdf

Irrigation management tips:

- Filling the soil moisture profile at sowing time is important, and pre-irrigation has been a recommended practice. However, in recent dry seasons, growers have chosen to water-up, enabling them to incorporate pre-emergent herbicides. Ensure that seed placement allows at least 7 cm of soil above the seed if using Balance® or simazine and that the soil surface is left flat to prevent herbicide leaching into the plant furrow.
- Generally, in-crop irrigation should start early when there is a soil moisture deficit of 30–40 mm (or 60–70% of field capacity). Soil moisture deficit is more important in scheduling irrigations than plant growth stage.
- Irrigations should also commence prior to flowering to prevent impacts of moisture stress and high temperatures on grain size, quality and yield. This is particularly important with Kabuli types, where premiums are paid for larger seed sizes.
- The higher clay content or soil bulk density, the higher is the risk of waterlogging from slow water infiltration and subsequent slow draining. It is a greater risk to irrigate these soils once flowering and podding has commenced. If in doubt, do not water. [25]
- If the ground has cracked open irrigation should be avoided as this allows water to enter the root zone and cause waterlogging, leading to flower abortion and risking plant death.

More information

L Lake, V Sadras (2015). The critical period for yield determination in chickpea

1.11 Yield and targets

1.11.1 Seasonal outlook

The online tool CropMate was developed by NSW DPI and can be used in pre-season planning to analyse average temperature, rainfall and evaporation (Figure 21). It provides

[25] NSW DPI (2012) Surface irrigated chickpeas. Farm Enterprise Budget Series. NSW Department of Primary Industries http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/176053/North-Irrig-surface-chickpeas-2012.pdf

seasonal forecasts and information about influences on climate, such as the impact of Southern Oscillation Index (SOI) on rainfall.

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

Figure 21: 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 2015'.

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.

Australian CliMate is a suite of climate analysis tools delivered on the web, and on iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records on questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, as 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 relative to previous seasons, based on heat sum?

More information

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

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

- 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. [26]

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. [27]

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

K Verburg, J Which (2016), Drivers of fallow efficiency: Effect of soil properties and rainfall patterns on evaporation and the effectiveness of stubble cover

1.11.2 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. [28]

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?

An on-farm research approach was used to compare the traditional long fallow with a millet fallow 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. [29]

There are few options for the control of problem grass weeds such as ABYG and FTR while the millet crop is growing.

It has also been observed that in wet summers, *Fusarium* spp. fungus, which causes crown rot, can colonise and survive on some species of millet.

[26] Australian CliMate—Climate tools for decision makers, www.australianclimate.net.au

[27] 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

[28] 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

[29] 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.

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?

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

This information aids 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 particularly important 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, perhaps 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? [30]

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

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. [31]

More information

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

1.11.3 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.

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

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

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 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. [32]

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 (Table 16 and Table 17).

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. [33]

Table 16: 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

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

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

More information

https://dl.sciencesocieties.org/publications/meetings/download/pdf/2013am/78228

Table 17: 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 grain-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, 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 22).

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).

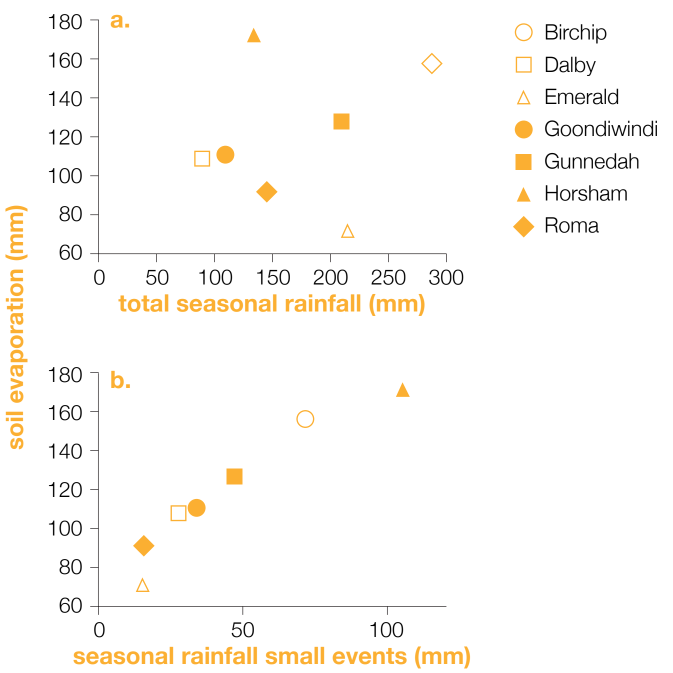

Figure 22: Simulated soil evaporation is (a) unrelated to seasonal rainfall and (b) closely related to rainfall in small events (i.e. equal to or below 5 mm).

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

1.11.4 Double crop options

Chickpeas are a very good crop to double crop out of an early sorghum crop straight back into chickpea, avoiding the need for long fallow in wet summers. This is possible because chickpea needs less water than wheat.

1.12 Disease status of the paddock

Three pre-planting practices are paramount for managing chickpea diseases: stubble management, controlling volunteers and weeds, and paddock selection.

Floods and surface water flows can distribute inoculum of *Phoma rabiei* (formerly *Ascochyta rabiei*, causing Ascochyta blight) and *Botrytis cinerea* (causing Botrytis grey mould) as well as *Sclerotinia*, *Phytophthora root rot* and root-lesion nematodes across large areas of the northern region cropping belt.

Some diseases such as Ascochyta blight are considered 'community diseases', so what happens in a neighbouring paddock or even several kilometres away can affect crops.

Chickpea varieties in the northern region are susceptible to both species of *Sclerotinia*, and all varieties are susceptible to Botrytis grey mould (Table 18).

However, there are varying levels of resistances to Ascochyta blight and *Phytophthora* so growers should consider planting a variety with the highest levels of resistance to either or both. [34]

More information

http://www.pulseaus.com.au

http://www.grdc.com.au/Research-and-Development/Major-Initiatives/PBA/PBA-Varieties-and-Brochures

[34] GRDC (2011) What to consider before planting chickpeas. GRDC Media Centre 6 June 2011

Table 18: Resistance ratings of some northern region varieties to Phoma rabiei (Ascochyta rabiei), Phytophthora medicaginis and Botrytis cinerea

Variety	*Phoma rabiei*	*Phytophthora medicaginis*	*Botrytis cinerea*
PBA HatTrick⚘	MR/R	MR	S
Flipper⚘	MR	MS	S
PBA Boundary⚘	R/MR	MS	S
PBA Monarch⚘	MS	S	S
Yorker⚘	MS/MR	MR	S
Jimbour⚘	S	MS/MR	S
Kyabra⚘	S	MS	S
Genesis090	R	VS	VS
Genesis425	R	MS	S
Almaz⚘	MS/MR	VS	S

Resistance ratings are for situations of low–moderate disease pressure. In a season such as 2010 when repeated cycles of infection occur, even MR varieties can have yield-reducing levels of disease. M, moderately; V, very; R, Resistant; S, susceptible

1.12.1 Soil testing for disease

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 (RLN) (*Pratylenchus neglectus* and *P. thornei*)
- stem nematode (*Ditylenchus dipsaci*)

More information

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

Crown Analytical Services

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.

1.13 Nematode status of the paddock

The RLN *Pratylenchus thornei* (Pt) is widespread in cropping soils through central and northern NSW. Although mainly considered an issue in wheat crops, Pt also infects chickpeas, with yield losses of 20–30% previously recorded in intolerant varieties. Chickpeas are also susceptible to Pt, which means that this nematode colonises the root systems and builds up numbers in the soil. This is especially an issue in the northern region where chickpeas remain the main winter break crop grown in rotation with winter cereals. However, chickpea varieties can vary in their levels of resistance to Pt; this is related to the extent to which they build up Pt populations in the soil, which then dictates the effect on subsequent crops in the rotation. Varieties that are more susceptible allow greater multiplication of Pt in their root systems over a season. The higher the resulting Pt population left in the soil following chickpeas, the greater is the potential for a negative impact on the yield of subsequent crops.

Pratylenchus thornei costs the wheat industry AU$38 million annually. [35] Including the secondary species, *P. neglectus*, RLN is found in three-quarters of paddocks tested. [36]

More information

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

1.13.1 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 paddocks 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 its future contamination. [37]

More information

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

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

Crown Analytical Services

Testing of soil samples taken either before a crop is sown or while the crop is in the ground provides valuable information. There is a great deal of spatial variation in nematode populations within paddocks. It is critical to follow sampling guidelines to ensure accurate results.

A chickpea variety trial was conducted at Come-by-Chance, north-western NSW, in 2010 under the National Variety Trial (NVT) network funded by GRDC. The harvested plots were left intact and soil cores were taken in March 2011 to assess the effect of chickpea variety choice on the build-up of Pt in the soil under the 2010 crop. This type of testing determines the resistance of chickpea varieties to Pt.

Desi chickpea entries varied significantly in their effect on the build-up of Pt populations in the soil over the 2010 season (i.e. resistance level). Pt populations multiplied 1.8 times under the most resistant entry, CICA1009, and up to 8.4 times under the most susceptible entry, CICA0907. Variety choice can also have a significant impact on the build-up of Pt populations within the soil, with numbers about 2.3 times higher after the very susceptible variety Kyabra⍉ than after moderately susceptible varieties such as PBA Boundary⍉, Jimbour⍉ or PBA HatTrick⍉.

All current Desi chickpea varieties and advanced lines are susceptible to Pt, and they will build up soil populations within the rotation. However, variety choice can still influence the extent of build-up of Pt, because significant differences exist in the resistance of chickpea varieties to Pt.

More information

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

As highlighted in this study, the NVT network is a valuable potential source of reliable field assessments of nematode resistance levels in varieties and near-release lines across a range of crop types.

Breeding programs need to focus on developing and releasing chickpea varieties with good levels of tolerance to Pt to limit yield impact on chickpea crops. However, released varieties also need to have improved levels of resistance to Pt to limit the build-up of this widespread pest within cropping systems in the northern region. [38]

[35] 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

[36] 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

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

[38] S Simpfendorfer, M Gardner, G McMullen (2013) Desi chickpea varieties differ in their resistance to the root lesion nematode *Pratylenchus thornei*—Come-by-Chance 2010. Northern Grains Region Trial Results, autumn 2013. pp. 114–116. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

1.13.2 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 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 Pt and *P. neglectus*.

Summer crops have an important role in management of RLN. Research shows when Pt 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. [39]

For more information on nematode management, see Section 8, Nematodes

More information

'Management of root-lesion nematodes in the northern grain region': http://www.daf.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

1.14 Feral pests

Significant losses of plant populations have been caused by feral pigs seeking out the germinating seed from in the soil. In areas adjoining pig-infested scrub, damage can be significant enough to justify re-planting areas.

More information

http://www.daf.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/

http://www.feral.org.au/

http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/vertebrate-pests

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