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GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 1

PLANNING AND PADDOCK PREPARATION

PADDOCK SELECTION | PADDOCK ROTATION AND HISTORY | UNDERSTANDING SOILS AND PULSE CROP CONSTRAINTS | FALLOW WEED CONTROL | FALLOW CHEMICAL PLANT-BACK EFFECTS | SEEDBED REQUIREMENTS | SOIL MOISTURE | YIELD AND TARGETS | DISEASE STATUS OF PADDOCK | NEMATODE STATUS OF PADDOCK | TESTING SOIL FOR DISEASE AND NEMATODES | INSECT STATUS OF PADDOCK

Planning/Paddock preparation

Key messages

- To reduce disease risk, 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.
- Avoid paddocks with high weed burdens, as chickpeas provide poor competition for weeds.
- Chickpea is well suited as a winter crop to the medium rainfall (300–500 mm) areas of south-eastern Australia. Crop growth during winter months is very limited but accelerates with warmer weather in spring (Figure 1).
- Kabuli types are less tolerant than Desi types to dry conditions, as they require more moisture to achieve a satisfactory grain size and yield. Desi types require above 350 mm annual rainfall and Kabuli types need more than 400 mm, though it's important to check with agronomist for local recommendations.
- Chickpea is an advantageous crop rotation because of its nitrogen fixing ability. However, it is a poor competitor against weeds and can be susceptible to nematodes.
- Consider herbicide residual and plant-back effects before sowing.
- Prior to sowing, it is important to consider disease, nematode, and pest management by knowing paddock history and testing soils.

Figure 1: *Ideal conditions for chickpea growth.*

Source: Pulse Australia.

MORE INFORMATION

Checklist for Chickpea growers in the Southern region.

VIDEOS

1. Growing profitable pulses.

1.1 Paddock selection

Key points

- Well-drained soils with a pH above 5.5 in Calcium Chloride ($CaCl_2$), heavy deep clays, heavy loam, sandy loam and Salmon Gum soils. Avoid soils with a pH below 5.5 ($CaCl_2$), saline soils, high boron soils and Wodjil soils. Chickpeas have poor tolerance of low pH, where aluminium toxicity can be a problem.
- Check soil tests to determine if the soil type is suitable for chickpea production, i.e. pH 5.2–8.0, loams to self-mulching clays, sufficient stored soil moisture, absence of herbicide residues and absence of constraints such as sodicity, salinity/chloride, high bulk density, and potential for waterlogging.
- Chickpeas grow poorly on sands, on tight hard-setting clays and acidic soils.
- A soil structure and slope which allows good drainage—avoid shallow soils.

- Check herbicide use over the previous 12–24 months and seek advice regarding any potential residue problems prior to sowing. Make sure there is little or no risk of sulfonylurea carry over.
- A low broad-leaf weed burden.
- Soil surface needs to be relatively flat and even after sowing for harvest.
- Chickpea crops should be separated from 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. down slope and on flood plains. This helps to reduce the spread of Ascochyta blight, a foliar/stubble-borne disease.
- A paddock with a history of medics or lucerne should also be avoided due to potential risk of phytophthora infection. Also consider past history of sclerotinia and rhizoctonia infection.

Aim to direct drill chickpeas into standing cereal stubble. Crops reliably yield 10% higher when established this way. 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. Harvest losses are much higher in rough or uneven paddocks, particularly in dry seasons when crop height is reduced. Sticks or rocks, eroded gullies or gilgais ('melon' or 'crab' holes) will prevent headers operating at low cutting height. This is particularly important when using headers with wide fronts. Small variations in paddock topography can lead to big variations in cutting height across a wide front and a subsequent increase in harvest losses.

Moisture supply can significantly affect crop maturity. Changes in soil type and moisture holding capacity across a paddock can lead to uneven crop maturation, delayed harvesting, and increased risk of weather damage or high harvest losses. Paddocks that have even soil types are relatively easier to manage, and are preferred for chickpeas. [1]

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.

1.1.1 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 Pulse Australia. Chickpea production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

1.1.2 Soil

Chickpea crops are best suited to well-drained loam and clay loam soils that are neutral to alkaline (pH 6.0–9.0) and have good water holding capacity.

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

- soil type—loams to self-mulching clays
- pH 5.2–8.0 - saline soils ECe >1.5 ds/m will cause a yield reduction
- salinity, chloride—avoid electrical conductivity (EC) levels >1.5 dS/m
- sodicity (ESP) >1.0 surface or >5.0 in subsoil can limit yield
- High boron and soil chloride levels >600 mg/kg in sub-soil layers will severely limit root growth, depth, and water extraction from the soil.
- potential waterlogging problems: Avoid dense soils (bulk density >1.5) or compacted soils or areas where free water does not drain away and/or remains saturated. Spring sowing may be an option in higher rainfall areas. [2]
- amount of stored soil moisture and received rainfall, noting their potential impact on herbicide residues[3]

For more information on causes and management of waterlogging, salinity, sodicity, and chloride issues, see Section 14: Environmental issues.

Chickpeas will not grow in light acid soils and areas prone to waterlogging should be avoided. Chickpea crops must be harvested close to the ground so stony paddocks or fields with uneven soil surface (e.g. gilgai) should be avoided.

Chickpea are susceptible to hostile sub-soils, with boron toxicity, sodicity, and salinity causing patchiness in affected paddocks. Chickpea will not tolerate soils with any exchangeable aluminium present. Tolerance to sodicity in the root zone (to 90 cm) is less than 1% exchangeable sodium (ESP) on the surface and less than 5% ESP in the subsoil. [4]

Subsoil

Chickpeas are recommended for soils with a surface pH ca of 5.0, if sub-soil pH rises to above 5.5 within 10–15 cm of the surface. [5]

Subsurface pH is of importance to the break crop in the rotation. Knowing the pH at depth is vital for an effective break crop, particularly if the surface soil is testing at or above the target of pH 5.5.

Crop yield variability and productivity below potential yield on neutral and alkaline soils in the semiarid Mediterranean-type environments of south-eastern Australia have been attributed, in part, to variable rooting depth and incomplete soil water extraction caused by physical and chemical characteristics of soil horizons below the surface. These characteristics are referred to as subsoil constraints. Information concerning subsoil constraints typical of neutral and alkaline soils in south-eastern Australia, principally salinity, sodicity, dense soils with high penetration resistance, waterlogging, nutrient deficiencies, and ion toxicities was recently reviewed. The review focused on information from Australia (published and unpublished), using overseas data only where no suitable Australian data is available.

An assessment of the effectiveness of current management options to address subsoil constraints is provided. These options are broadly grouped into three categories:

2 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

3 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

4 Pulse Australia. Chickpea production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

5 Parker W. DAFWA (2014). Crop Updates – Break crops being sown onto unsuitable soils, unsuspectingly.

(i) amelioration strategies, such as deep ripping, gypsum application or the use of polyacrylamides to reduce sodicity and/or bulk density, deep placement of nutrients or organic matter to overcome subsoil nutrient deficiencies, or the growing of 'primer' crops to naturally ameliorate the soil;

(ii) breeding initiatives for increased crop tolerance to toxicities such as salt and boron; and

(iii) avoidance through appropriate agronomic or agro-engineering solutions.

There a number of difficulties in identifying the impact of any single subsoil constraint to crop production on neutral and alkaline soils in south-eastern Australia, given that multiple constraints may be present. Difficulty in clearly ranking the relative effect of particular subsoil constraints on crop production (either between constraints or in relation to other edaphic and biological factors) limits current ability to develop targeted solutions designed to overcome these constraints. Furthermore, it is recognised that the task is complicated by spatial and temporal variability of soil physicochemical properties and nutrient availability, as well as other factors such as disease and drought stress. Nevertheless, knowledge of the relative importance of particular subsoil constraints to crop production, and an assessment of impact on crop productivity, are deemed critical to the development of potential management solutions for these neutral to alkaline soils. [6]

MORE INFORMATION

Subsoil constraints to crop production on neutral and alkaline soils in south-eastern Australia: a review of current knowledge and management strategies.

1.1.3 Stubble retention

Chickpeas fit well into stubble retention systems with no tillage, and serve their wider role in crop rotations and farming systems. Retention of adequate plant residues on the surface is important to protect the soil from erosion both during growth and after harvest. This will not affect chickpea germination and growth, and can improve establishment on hard-setting, surface-crusting soils. Sowing into cereal stubble reduces soil moisture losses from evaporation. [7]

Chickpeas established by direct drilling into standing cereal stubble reliably yield 10% higher than when using other planting techniques (Photo 1). [8]

6 Adcock, D., McNeill, A. M., McDonald, G. K., & Armstrong, R. D. (2007). Subsoil constraints to crop production on neutral and alkaline soils in south-eastern Australia: a review of current knowledge and management strategies. *Animal Production Science*, *47*(11), 1245-1261.

7 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

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

VIDEOS

2. Stubble Management.

3. GCTV15: Stubble height Pt. 1.

4. GCTV15: Stubble height Pt. 2.

5. GCTV4: Burning for stubble retention.

6. Southern farm groups cutting through stubble issues.

Photo 1: *Better chickpea yields are achieved by sowing into cereal stubble.*

Source: Flickr.

There are advantages and disadvantage to stubble retention, with high stubble loads potentially causing problems for growers in the following year (Table 1).

Table 1: *Advantages and disadvantages in retaining stubble. Based on information from the GRDC.*

Advantages of stubble retention	Potential disadvantages of stubble retention
Retained stubble provides excellent ground cover (>2.5 t/ha), thus reducing wind and water erosion;	Seeder blockages impact on plant establishment;
increases rainfall infiltration;	Stubble provides ideal habitat for pests to survive;
reduces moisture evaporation (>4.5 t/ha);	physically intercepts herbicides;
eliminates the need to burn, bale or incorporate; and	increases frost risk;
recycles nutrients back into the soil.	carries over diseases; and
	increases potential for nitrogen tie-up.

For more detailed information, see Wide rows and stubble retention and Profitable stubble retention systems for the high rainfall zone.

Stubble and its impact on temperature in chickpea crops

Key points:

- Chickpea sown into flattened residue had lower (av. 1.0°C) minimum temperatures compared to standing residue.
- Chickpea sown into flattened residue had higher (av. 3.4°C) maximum temperatures compared to standing residue.
- Stubble thresholds are unknown at this stage.

Stubble affects soil physical properties such as temperature and moisture. The effect on temperature is due to landscape features such as whether a paddock was on top of a hill, on a hill slope, or at the lower end of a slope because cold air (due to its higher density) tends to flow downhill and settle in the lower parts of the landscape, leading to colder pockets where temperatures decline the most.

Stubble cover also affects air and soil temperature. During the day the stubble reflects radiation due to its 'albedo'. A bare, darker soil absorbs more solar radiation than a stubble-covered soil and warms up more readily. The stubble also acts as insulation—it contains a lot of air which is a poor conductor of heat.

Finally, the stubble affects the moisture content of the soil. It takes more heat to warm up moist, stubble-covered soil than dry, bare soil. This causes soil temperature of a bare soil to be higher than stubble-covered soil during the day (especially in the afternoon). At night, however, the bare soil loses more heat than stubble-covered soil due to the lack of insulation (the air-filled mulch being a poorer heat conductor). This is especially noticeable when skies are clear. The air above the bare soil is therefore warmer during the night than the stubble-covered surface. This can affect canopy temperature profiles in crops.

In a recent trial, the temperature of stubble and the subsequent impacts on chickpea crops in NSW were explored.

Temperature sensors were placed between 1.0 m wide rows in:

1. plots sown into standing stubble with bare soil between chickpea rows
2. plots sown into flattened stubble with surface stubble between chickpea rows

Standing stubble plots with bare soil between rows:

- had minimum temperatures 1°C warmer at the base of the canopy than surface-stubble plots during vegetative period
- had maximum temperatures -3.4°C cooler at the base of the canopy than surface-stubble plots during flowering and grain fill period
- recorded five days with maximum temperatures >35°C compared to 27 days of maximum temperatures >35°C where stubble was flattened.

Plant components for the stubble treatments are shown in Table 2. Plants sown into bare soil between standing wheat rows had higher grain yields which were achieved through more pods being set and more seeds being produced per square metre.

Table 2: *Effect of stubble treatment on selected plant components.*

Stubble	DM/m²(g)	Grain/m² (g)	Seeds/m²	Pod No/ m²	Seeds/ pod	HI
Bare soil	706	270	1072	815	1.3	0.38
Straw	526	226	908	538	1.7	0.43

Source: GRDC.

Conclusions

- Flattened surface residue led to lower minimum temperatures in crop than standing residue.
- Flattened residue had higher maximum temperatures during flowering and grain fill than standing residue.
- Flattening and spreading residue can increase crown rot infection in the following wheat crop.
- Keep wheat stubble standing in defined rows and sow chickpeas between wheat rows. [9]

1.1.4 Rainfall

Chickpeas are not well-suited to the lower rainfall, hotter areas, although the plants will set seed under warmer conditions where other pulse crops are likely to fail. Cool, wet conditions are more likely to stimulate foliar diseases and these can adversely affect seed set and yield. Desi varieties should only be grown in areas where the

VIDEOS

7. Crop sequencing in the Mallee.

9 Verrell, A. (2016). GRDC Update Papers - Stubble and its impact on temperature in chickpea crops. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Stubble-and-its-impact-on-temperature-in-chickpea-crops

annual rainfall is greater than 350 mm. Sowing is best carried out from early May to early June, with early sowing recommended for the lower rainfall areas. Kabuli varieties are later maturing and should only be grown in areas where the annual rainfall is over 400 mm. As a higher value crop, Kabuli types are often grown on fallow where extra moisture can mean larger seed. [10]

1.1.5 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. Dense, impermeable subsoils (high bulk density) can lead to extensive development of lateral roots in the top 30 cm of soil, with only weak development of the taproot. 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.

1.1.6 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 nitrogen fixation, so deficiency of these trace elements can lead to poor nodulation.

For more information, see Section 5: Nutrition and Fertiliser.

1.1.7 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.

Biological inputs

Key points:

- When evaluating a biological input for grain production, it may be useful to consider whether the input will alleviate yield constraints.
- The major yield constraints in the southern grain-growing region are high soil density, sodicity, and acidity.
- The biological inputs with the most potential to help alleviate these yield constraints are manure, compost, vermicompost, biochar, and some biostimulants.

The southern region has soils with generally low fertility and many have subsoil constraints, such as salinity, sodicity and toxic levels of some elements. However, soils in this region are diverse and some areas have very productive soils. Crop production systems in the region are varied and include many mixed farming enterprises that have significant livestock and cropping activities.

Yield potential in the southern region depends on seasonal rainfall, especially in autumn and spring, and there is less dependence on stored soil moisture than in the northern region.

In the southern grain-growing region, the most significant yield constraints are high soil density, sodicity, and acidity.

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10 Pulse Australia. Chickpea production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Alleviating yield constraints using biological inputs

When the high density of a soil constrains yield, applying manure, compost, vermicompost or biochar may increase crop growth and yield. Because these biological inputs are largely composed of organic matter, they can increase soil aggregation and pore space in soil, both of which can decrease soil compaction and the bulk density of soil. However, if yield is being constrained by subsoil compaction, manure, compost or biochar are unlikely to alleviate this constraint unless they are applied below the soil surface or incorporated into soil.

When yield is constrained by soil sodicity, crop growth and yield may be increased by applying manure, compost, vermicompost or biochar. These biological inputs do not actually decrease the sodicity of soil. Instead, the high organic matter content of these inputs means that they may help alleviate the poor structural properties associated with sodic soils. However, when sodicity constrains yield, the simplest and most economic way of alleviating this constraint is applying gypsum to soil.

When soil acidity constrains yield, applying compost or biochar may increase crop growth and yield. Compost and biochar both have the potential to increase the pH of acidic soils. Compost can also have a strong pH buffering capacity, which can help minimise future changes in soil pH. Although compost and biochar can increase soil pH, when soil acidity constrains yield, the simplest and most economic way of alleviating this constraint is applying lime to soil. [11]

1.1.8 Problematic paddocks

Stones and sticks are a concern in poorly or recently cleared country if not able to be rolled in. 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.

1.1.9 Soil pH

Key points:

- Soil pH is a measure of the concentration of hydrogen ions in the soil solution. It is measured in water or $CACl^2$ solution, providing slightly different readings.
- Low pH values (<5.5) indicate acidic soils and high pH values (>8.0) indicate alkaline soils.
- Soil pH between 5.5 and 8 is not usually a constraint to crop or pasture production.
- In South Australia, more than 60% of agricultural soils are alkaline.
- Outside of the optimal soil pH range, microelement toxicity damages crops.

Hydrogen ion concentration in the soil is called pH and is influenced by chemical reactions between soil components and water. Soil pH is affected by the varied combinations of positively charged ions (sodium, potassium, magnesium, calcium, aluminum, manganese, and iron) and negatively charged ions (sulfate, chloride, bicarbonate, and carbonate). Soil pH directly affects the concentration of major nutrients and the forms of microelements available for plant uptake and can result in deficiencies or toxicities (Figure 2).

11 Soilquality.org. Biological inputs – Southern Grain growing region. http://www.soilquality.org.au/factsheets/biological-inputs-southern-grain-growing-region

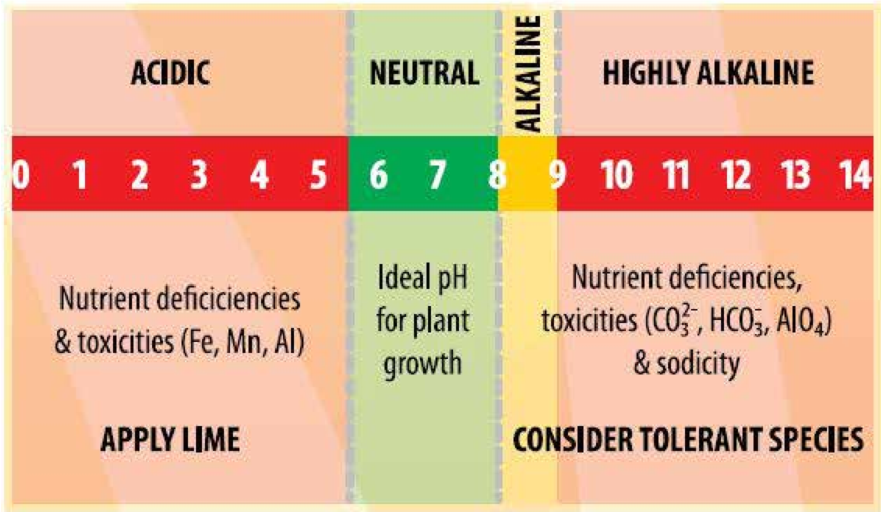

Figure 2: *Classification of soils on the basis of pH (1:5 soil:water), the implications for plant growth and some management options.*

Source: Soilquality.org.

Alkaline soils

Soil alkalinity is mainly caused by bicarbonates and carbonates, although phosphates, borates, and some organic molecules can contribute. In a soil with pH from 7–8.2, bicarbonates and carbonates of calcium and magnesium dominate. Calcareous soils contain from 1–90% lime material as calcium carbonates and these sparingly soluble salts cause the soil to have a pH of 8.0–8.2, which is not a severe problem for plant growth or agricultural production. Problems are encountered in alkaline soils when sodium occurs or accumulates and forms salts such as sodium bicarbonate and sodium carbonate. These are highly soluble and increase the soil pH above 8. When the pH is more than 9, the soils are considered highly alkaline and often have toxic amounts of bicarbonate, carbonate, aluminium, and iron. Nutrient deficiency is also likely to be a major problem and the high amount of exchangeable sodium in these soils reduces soil fertility.

Managing soil pH

Acid soils

Acid soils can be economically managed by the addition of agricultural lime, usually crushed limestone. Sufficient lime should be added to raise the pH to above 5.5. The amount of lime required to ameliorate acid soils will vary, mainly depending on the quality of the lime, soil type, and how acidic the soil has become.

Soils prone to becoming acidic will need liming every few years. Seek advice on an appropriate liming regime from your local agricultural advisor.

Alkaline soils

Treating alkaline soils by the addition of acidifying agents is not generally a feasible option due to the large buffering capacity of soils and uneconomic amounts of acidifying agent (e.g. sulfuric acid, elemental sulfur, or pyrites) required.

Gypsum will reduce sodicity and this can reduce alkaline pH to some extent. Growing legumes in crop rotation may help in sustaining any pH reduction.

In high pH soils, using alkalinity tolerant varieties of crops and pasture can reduce the impact of high pH. [12]

12 Soiquality.org. Soil pH- South Australia. http://www.soilquality.org.au/factsheets/soil-ph-south-austral

1.1.10 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. [13]

1.1.11 Soil testing

Key points:

- The approach taken will be defined by the purpose of the investigation, variability in the area sampled, and the analysis and accuracy required.
- For many soil quality parameters, sampling is typically done to 10 cm. Although 30 cm is required for carbon accounting purposes, stratification below 10 cm is recommended (e.g. 10–20, 20–30 cm).
- The sampling strategy should either integrate or describe the variation within the sampling area.
- Samples should be air dried or kept below 4°C prior to analysis. For biological measurements, it is best to analyse as soon as possible.

Before you can decide how you are going to soil sample, you need to be clear about the purpose of your sampling. Different sampling approaches may be required depending on what you are sampling for, the soil type, the management unit (e.g. paddock), soil spatial variability (changes in soil type, dunes-swales etc.), the accuracy required of the result, and the value given to the information provided (Photo 2). So before you start, define very clearly the question you are asking of your soil samples.

Consult a professional soil scientist, agronomist, or your analytical laboratory to be sure that your soil samples are taken at the right time, from the right depth, the right place, in the appropriate number, and are stored in such way that the analysis required is not compromised. If quantitative soil analyses (kg/ha) are required, then soil bulk density must also be measured and this requires considerable care. [14]

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

14 Soilquality.org. Soil sampling for soil quality – South Australia. http://www.soilquality.org.au/factsheets/soil-sampling-for-soil-quality-south-australia

Photo 2: *To be meaningful, soil sampling needs to take into account spatial variation in the soil condition. Differences in soil type, nutrient status and other soil properties may be exhibited within a paddock.*

Source: Soilquality.org.

Accurate soil tests allow landholders to maximise the health of their soils and make sound decisions about fertiliser management to ensure crops and pastures are as productive as possible.

Identifying potential soil limitations enables landholders to develop an action plan (such as an appropriate fertiliser program) to reduce the potential of 'problem' paddocks.

Soil health looks at all aspects of the soil together, including the physical, chemical and biological components, rather than each component separately.

Healthy soil requires a balance between inputs and outputs and regular soil tests provide a valuable monitoring tool to keep an eye on soil nutrient levels and other key characteristics such as pH and salinity.

A soil imbalance can affect the ability of plants to absorb any applied fertiliser, wasting time and money. A combination of soil tests, on-farm observations, and historical records will assist in determining soil health.

Soil testing is a useful tool to provide information to support decisions about fertiliser application. However, it is important to combine test results with other information, such as specific crop or pasture requirements, available funds and fertiliser cost, methods of application, and potential income from the crop or pasture being grown.

Accurate results

Soil test results are only as accurate as the samples taken from the paddock and how they are handled leading up to laboratory analysis. If the samples do not truly reflect the soils in a certain paddock, the test results are likely to suggest an inaccurate picture of soil fertility.

Sampling not only depends on how the sample is taken but when and where.

There are four main steps in soil sampling:

- collecting representative samples
- laboratory analysis
- interpretation of test results on which to make decisions
- recording the results and actions taken for future reference.

Taking the test

There is more to soil testing than analysing the soil's nutrient status. The process incorporates the sampling procedure, soil analysis and interpretation of the results leading to a sound recommendation.

Before collecting soil samples, consult a local agronomist to discuss the need for additional tests such as deep soil nitrogen tests. In most soils the nutrients are concentrated in the top 10 cm of soil, so ensure samples are consistently taken to this depth.

When to collect samples

Changes in soil moisture, plant growth stage, and decomposition of organic matter all affect soil nutrient levels. For example, available nutrients can be low in soil samples collected during spring as nutrients are still in the plant and are not returned to the soil until after decomposition.

Check with your local agronomist as to the best time to collect soil samples in your area. Most comparisons are based on mid–summer (January to March) sampling when the soil is dry. For mobile nutrients like nitrate or potassium, deeper sampling may be required on the more sandy soils. Sampling to the rooting depth of a crop of interest might be useful for these nutrients or when studying water availability; otherwise it is generally too onerous. When assessing soil carbon stocks for accounting or budgeting purposes, a sampling depth of 30 cm is required to conform with standard accounting procedures. When sampling below 10 cm, soil samples are usually stratified by depth increments (e.g. 0-10, 10-20, 20-30 cm), depending on the objectives. When characterising a soil for the first time, sampling corresponding to the different soil layer depths (horizons) is often useful. Plant litter on the soil surface is not usually included in soil samples while plant root material is usually included, although generally sieved out prior to analysis.

Regular tests build better profile

Because many factors influence soil test results, soil analysis for one season is not conclusive. Subtle differences in soil type can impact significantly on the availability and exchange of nutrients between the soil and plants, so it is important to test soil regularly.

Testing the soil at the same time each year improves the comparison of results between years and builds a clear profile of soil health over time.

It is also important to send samples to the same laboratory for testing as results between laboratories cannot be compared easily.

Collect enough samples to make up a representative picture of a paddock. It is better to over-sample, as this will provide a more accurate picture of the soil and will help reduce unnecessary fertiliser application.

Selecting your samples

Sampling often limits the success of soil testing. One hectare of soil to a depth of 10 cm contains about 1300 t of soil. A 10 g subsample sent to a laboratory represents only one part in 1300 million. So ensure your samples are representative.

To increase test result accuracy, avoid sampling soil near fences, trees, troughs, headlands, dams, stock tracks and clumps of manure, fertiliser dumps, fertiliser bands from the previous year, burnt heaps, areas of abnormally good or poor growth or poorly drained areas.

Also avoid collecting samples from areas where fertiliser, gypsum, or lime have been applied during the preceding three months. Wet soil can alter test results due to microbial activity and mineralisation.

Account for variability

Variability of soil is often overlooked. Even individual paddocks often have variations in soil surface depth, soil type, and nutrient levels, which can be significant over relatively short distances.

Many soil types can be found in a single paddock. This, combined with management practices, can lead to varying nutrient levels within and across paddocks. Even if the paddock has a uniform single soil type, stock can spread nutrients unevenly through urine and dung. Management can concentrate or spread nutrients through clearing, burning, grazing or hay production.

Where soil differences within a paddock are obvious and areas can be treated differently, take separate samples from each area.

Where there is more than one soil type, take about 20 cores from each major soil type. Ensure each soil type is sampled and labelled separately to allow for individual analysis.

To increase productivity on larger properties, it is worthwhile classifying the land and soil types and ensuring samples are only collected from within a specific land and soil type.

Sampling sites

Take samples from across a paddock using a dedicated soil sampling tube or 'pogo'. Take at least five (preferably more) samples per hectare, covering the entire area.

Keep in mind that a hectare is 100 m by 100 m and to take five samples diagonally will involve taking samples about 30 m apart in a zig-zag pattern.

If the paddock is predominantly of one soil type take at least 40 cores, each to a depth of 10 cm. For each soil type, bulk all samples together, thoroughly mix and take a 500 g subsample to be sent to the laboratory with clear labels.

Note in your records the pattern that you used to collect samples. Following the same pattern in future years will provide a clearer picture of soil fertility trends.

Handle with care

Collect cores in a clean plastic bag and label clearly. Do not use second-hand containers or touch soil samples with bare hands, as this will contaminate the sample and affect the test results.

Air dry samples by leaving the top of the bag open to the air if there is a delay between sampling and posting. Send samples to the laboratory early in the week if possible to avoid postal delays over weekends.

Prepared soil sampling kits are available from most rural supply stores. If using an off-the shelf kit, read the instructions carefully as they may have specific instructions.

Interpreting the results

A number of laboratories are available to test and analyse your soil samples. Some services offer recommendations relating to the test results.

Contact your local agricultural consultant, agronomist, or rural supply store for the contact details of available soil testing and support services in your region.

How to take a soil sample

To obtain an accurate soil analysis, the sample cores need to be taken correctly. Before taking samples, plan how many samples are required and from where they will be collected throughout the paddock.

Ensure the stainless steel sampling tube and collection bags (use new bags for each sample) are clean before taking samples, including inside the steel tube. If using oils on clay soils, ensure they are free of nitrates and carbon.

Most soil samples are taken from the top 100 mm of surface soil. Adjustable soil sampling probes often will have marks at 100 mm intervals.

If no mark exists, set the depth stop at 100 mm using a ruler. It is vital all samples are taken from the same depth.

For large paddocks, plan to take at least 25 cores in a grid or zig-zag pattern as shown. Paddocks of more than 50 ha will require more core samples (minimum of 30 cores).

If there are two or three distinct soil types in a paddock of more than 100 ha, treat them as separate paddocks. It is recommended to take 4–8 samples within a paddock (each sample being at least 12–15 cores), each taken from within a land management unit in the paddock.

Before sampling, remove any debris from the soil surface, without disturbing the soil. Do not scuff away any plant material from the surface as this will lead to a loss of surface soil. Push in the sample tube straight until the depth stop contacts the ground.

Half-turn the sample tube and then remove it from the ground, taking care not to lose any soil from the end of the tube.

In light soils, the whole tube might need to be pushed toward the ground and a finger placed over the end of the core while the tube is parallel to the ground to ensure the soil does not fall out.

Place a sample bag over the upper end of the tube and invert as shown, emptying the core into the bag. Tap the tube with the palm of a hand to loosen the core if required.

Soil tests can be a great tool in determining the health of your soils and in turn, maximise their productivity. [15]

MORE INFORMATION

https://grdc.com.au/resources-and-publications/groundcover/ground-cover-supplements/ground-cover-issue-58-precision-agriculture-supplement/understanding-and-managing-differences-in-paddock-productivity

1.2 Paddock rotation and history

1.2.1 Break cropping

- A break crop is any crop sown to provide diversity to help reduce disease, weed, and pest levels in a paddock.
- Choice of break crop type is determined by soil type and regional climate; crop sequence is determined by market and agronomic factors.
- Sourcing regional information from research organisations, agronomists, consultants, other farmers, and industry bodies is essential when selecting the most suitable crop type and varieties.

Break crops generally refer to a pulse or oilseed crop grown instead of cereals. The decision not to grow wheat but to grow and choose a break crop is based on many factors including the relative profitability of the crops—yield by price, the cereal disease pressure, herbicide resistance and personal preference.

15 DAFWA (2016). Soil sampling and testing on a small property. https://www.agric.wa.gov.au/soil-productivity/soil-sampling-and-testing-small-property?page=0%2C2

IN FOCUS

Break cropping in the southern region

The Low rainfall crop sequencing project (LRCSP) is a collaboration between SARDI and five farming systems groups in the southern region to deliver five crop sequencing trials in the low rainfall zone of south-eastern Australia:

- Eyre Peninsula Research Foundation (EPARF) Site location: Minnipa, SA
- Upper North Farming Systems (UNFS) Site location: Appila, SA
- Mallee Sustainable Farming (MSF) Site location: Mildura, Vic
- Birchip Cropping Group (BCG) Site location: Chinkapook, Vic
- Central West Farming Systems (CWFS) Site location: Condobolin, NSW

Take home messages:

- Combined analysis of trials hosted by BCG and MSF show that first year effects of legumes are generally more reliable than oilseeds for improving subsequent wheat yield.
- Increased nitrogen supply could be measured up to two years following the break and played a key role in the break effects at Karoonda and Hopetoun where weed burden was low.
- Disease breaks tended to only last for one wheat growing season.
- Sites with a high grass weed burden require a two year break to reduce the weed seed bank to a level that enables consistent improvements in cereal production.
- Measuring the gross margin of production over a three–four year period showed that the inclusion of legume and canola breaks in the sequence was at least as profitable as continuous wheat.
- Two-year breaks can increase the variability in gross margins in the years breaks are implemented, but significant profit gains compared to continuous wheat were made at both sites for a small selection of treatments.

One year breaks trialled at Mildura showed benefits of 0.3 t/ha of extra wheat production following a legume or fallow and 0.1 t/ha following a brassica, but weed populations constrained cereal yields following a single-year break treatments.

Inclusion of most break options in the sequence was at least as profitable as continuous wheat. There were several examples where the inclusion of breaks in the sequence resulted in substantial potential profit gains. [16,17]

MORE INFORMATION

Break crop benefits in temperate wheat production.

The value of break crops in low rainfall farming systems and which ones perform best.

Achieving success with break crops in the Mallee farming system

PODCAST

Break crops prove their value in low rainfall zone.

16 McBeath T, Gupta V, Llewellyn R, Davoren B, Hunt J, Lawes R, Browne C, Ferrier D, Moodie M. 2014. GRDC Update Papers - Achieving success with break crops in the Mallee farming system https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Achieving-success-with-break-crops-in-the-Mallee-farming-system

17 Moodie M, Wilhelm N. (2016). GRDC Update Papers: The value of break crops in low rainfall farming systems and which ones perform best. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/The-value-of-break-crops-in-low-rainfall-farming-systems-and-which-ones-perform-the-best

1.2.2 Chickpeas as a rotation crop

Chickpea is a winter pulse crop well-suited to the southern region in rotation with cereal and canola crops. 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 (Table 3). 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 three years. For disease management, it is recommended to aim for a break of at least four years between chickpea crops. [18] 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. Following dun field peas or faba beans, leave two years before sowing chickpeas. It is almost impossible to grade volunteer peas out of chickpeas.

Table 3: *Advantages and disadvantages of including chickpeas as a crop rotation.*

Advantages	Disadvantages
Chickpea is a break crop that can be used successfully in rotations to effectively break the lifecycle of cereal root diseases like take-all, cereal cyst nematode and crown rot. Chickpea plants fix their own nitrogen. They have an extensive and deep root system. Chickpea can be sown relatively late compared to wheat, which can spread the demand for machinery and labour. Chickpeas can improve soil friability. Can expand weed-control options They don't require much additional equipment. Can be sown as an opportunity crop if seasonal conditions (full profile after summer rain) allow in lower rainfall districts. Assist in snail control as chickpeas are not attractive for snail multiplication.	Chickpea is less competitive against weeds than some other crops. Crop topping to prevent weed seed set is not recommended in chickpea due to later maturity than the weeds. Chickpea is not known to break up hard pans or compacted layers in the soil profile. Nematodes can be a drawback to planting chickpeas before wheat where *Pratylenchus* species (RLN) populations are high.

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. Well-grown chickpea crops have been found to contribute up to 51 kg N/ha to the subsequent cereal crop. [19] In one study, the benefit of chickpea was equivalent to the application of 60 kgN/ha as fertiliser. [20]

Wheat yields and protein in the past have tended to be poorer after chickpea crops than after other pulses. It is often better to follow chickpea with barley rather than wheat. While older chickpea varieties were a host for the root lesion nematode

18 Pulse Australia. Southern Pulse Bulletin PA 2012 #08. Chickpea disease management strategy. http://pulseaus.com.au/storage/app/media/crops/2012_SPB-Chickpea-disease-management.pdf

19 Cox, H. W., Strong, W. M., Lack, D. W., & Kelly, R. M. PROFITABLE DOUBLE-CROPPING ROTATIONS INVOLVING CEREALS AND PULSES IN CENTRAL QUEENSLAND.

20 Marcellos, H., Felton, W. L., & Herridge, D. F. (1993). Crop productivity in a chickpea-wheat rotation. In *Proceedings 7th Australian Agronomy Conference* (pp. 276-278).

VIDEOS

8. Over the Fence: Chickpea redeemed as 'soil conditioner'.

(Pratylenchus neglectus, and P. thornei), newer varieties are not as susceptible to root lesion nematode multiplication. Any potential yield loss in the cereal following chickpeas can be remedied by applying an additional 10–20 kg of nitrogen fertiliser to that cereal. [21]

The disadvantages of including pulses in the rotation are possible soil erosion losses due to the lower stubble levels produced and the chance of a greater volatility in prices associated with pulses. [22]

NOTE: Do not sow chickpea in field pea or faba bean stubble. Do not sow for two years after a dun field pea type or after faba bean. It is almost impossible to grade volunteer peas out. [23]

1.2.3 Pulse effects on cereal yield

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.

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 (chickpea is a poor host to crown rot, cereal cyst nematode and take-all) 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. However, it is important to remember that the benefits of N fixation from pulses is not guaranteed. 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 (Figure 3).

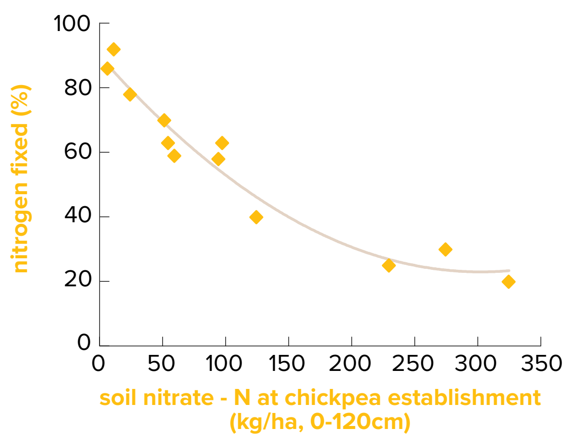

Figure 3: *Effect of soil nitrate nitrogen on nitrogen fixation by chickpea*

Source: J.A. Doughton *et al* 1993

21 Pulse Australia. Chickpea production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

22 Cox, H. W., Strong, W. M., Lack, D. W., & Kelly, R. M. PROFITABLE DOUBLE-CROPPING ROTATIONS INVOLVING CEREALS AND PULSES IN CENTRAL QUEENSLAND.

23 Pulse Australia. Chickpeas in South Australia and Victoria. http://www.pulseaus.com.au/storage/app/media/crops/2007_Chickpeas-SA-Vic.pdf

IN FOCUS

This paper outlines the nitrogen benefits of lupins, field pea, and chickpea to wheat production in south-eastern Australia.

The research showed chickpea was second to lupin in fixing soil N.

Nitrogen balances of narrow leaf lupin (*Lupinus angustifolius* L.), albus lupin (*L. albus* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), and barley (*Hordeum vulgare* L.) sown over a range of dates were examined in 1992 in a rotation study.

Yields, N_2 fixation, and crop residue N balances of the legumes were markedly influenced by sowing time, and superior performance of lupins over other species was related to higher biomass production and proportional dependence on N_2 fixation, together with a poorer harvest index.

Net soil N balance based solely on aboveground returns of N of legumes in 1992 through to harvest of wheat in 1993 was least for narrow leaf lupin-wheat (–20 kg N/ha), followed by albus lupin-wheat (–44), chickpea-wheat (–74), and field pea-wheat (–96). Corresponding combined grain N yields (legume+wheat) from the four rotations were 269, 361, 178, and 229 kg N/ha, respectively. The barley-wheat rotation yielded a similarly computed soil N deficit of 67 kg/ha. Data are discussed in relation to other studies on legume-based rotations. [24]

MORE INFORMATION

Armstrong, E. L., Heenan, D. P., Pate, J. S., & Unkovich, M. J. (1997). Nitrogen benefits of lupins, field pea, and chickpea to wheat production in south-eastern Australia. *Australian journal of agricultural research*.

Nitrate – N benefit for following cereals

The nitrate-N benefit from chickpea over a range of grain yields has been calculated from trials 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.

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

24 Armstrong, E. L., Heenan, D. P., Pate, J. S., & Unkovich, M. J. (1997). Nitrogen benefits of lupins, field pea, and chickpea to wheat production in south-eastern Australia. *Australian journal of agricultural research*.

MORE INFORMATION

Impact of crop rotations on profit, nitrogen and ryegrass seed bank in crop sequences in southern NSW.

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).

1.3 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 (Photo 3).

Photo 3: *Aerial shot of chickpea crops showing wide-scale crop loss due to sodic/saline conditions.*

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 5 and 6 below to assist in testing and diagnosis.

Table 5: *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 6: *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.

For more information on soil constraints on chickpeas, see Section 14: Environmental issues.

1.4 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 (Photo 4).

Photo 4: *Spraying weeds when small is the key to effective long fallow.*

Source: AGRONOMO.

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.

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 southern 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.

Trials exploring methods for summer grass control have found:

- Glyphosate-resistant and tolerant weeds (including annual ryegrass) are a major threat to our reduced-tillage cropping systems.
- Although residual herbicides will limit re-cropping options and will not provide complete control, they are key to successful fallow management.
- 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.
- Other weed management tactics can be incorporated, e.g. crop competition, to assist herbicide control.
- Cultivation may need to be considered as a salvage option to avoid seed-bank salvage. [25]

Stopping weed growth in the fallow can lead to yield increases in the following crop via several pathways. These include:

- Increased plant-available water
- A wider and more reliable sowing window
- Higher levels of plant-available N

25 GRDC (2012) Make summer weed control a priority—Southern region. Summer Fallow Management, GRDC Fact Sheet January 2012

VIDEOS

9. GCTV5: Managing summer fallow.

MORE INFORMATION

Summer weed fallow management: a reference manual for grain growers and advisers in the southern and western grains regions of Australia.

VIDEOS

10. Double knock application – a Grower's Experience.

- Reduced levels of weed-vectored diseases and nematodes
- Reduced levels of rust inoculum via interruption of the green bridge
- Reduced levels of diseases vectored by aphids that build in numbers on summer weeds, and
- Reduced weed physical impacts on crop establishment. [26]

1.4.1 Management strategies

How farming country is managed in the months or years before sowing can be more important in lifting water use efficiency (WUE) than in-crop management. Of particularly high impact are strategies that increase soil capture and storage of fallow rainfall to improve crop reliability and yield.

Practices such as controlled traffic farming and long term no-till seek to change the very nature of soil structure to improve infiltration rates and improve plant access to stored water by removal of compaction zones.

Shorter term management decisions can have an equal or even greater impact on how much plant-available water (PAW) is stored at sowing. These include decisions such as crop sequence/rotation that dictate the length of the fallow and amount of stubble cover, how effectively fallow weeds are managed, stubble management, and decisions to till/not to till at critical times.

While many factors influence how much plant available water is stored in a fallow period, good weed management consistently has the greatest impact. [27]

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. [28]

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 or when growing conditions are very favourable. Longer intervals are needed for weeds where translocation appears slower. 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 are rarely effective for salvage weed-control situations unless environmental conditions are exceptionally favourable.

Herbicide application

Broadleaf weeds and herbicide resistant grasses can cause major problems and a careful management strategy must be worked out well in advance. If possible, control weeds in the year prior to sowing chickpea or avoid paddocks with specific weeds that cannot be controlled by the available herbicides. [29]

Herbicide options for broad-leaved weed control are very limited. Growers will need to consider alternative control strategies if the standard treatment of post-sow pre-emergent Simazine is unlikely to provide adequate control, i.e.:

- The use of Balance®
- Use of trifluralin

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26 GRDC. (2014). Summer fallow weed management. https://grdc.com.au/Resources/Publications/2014/05/Summer-fallow-weed-management

27 GRDC. (2014). Summer fallow weed management. https://grdc.com.au/Resources/Publications/2014/05/Summer-fallow-weed-management

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

29 Pulse Australia. Chickpea production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

VIDEOS

11. Burning for weed and snail control.

MORE INFORMATION

Herbicide residues in pulses

- Inter-row cultivation is only an option in wide row systems
- Inter-row shielded sprayer (glyphosate) is only an option in wide row systems
- Post emergent Broadstrike® may be damaging (refer to label)
- Directed post-emergence sprays of Broadstrike® and/or Simazine

Herbicide options for grassy weed may be very limited if herbicide resistant ryegrass is present. Growers will need to consider alternative control strategies if the standard trifluralin pre-sowing treatment and post-sow pre-emergent Simazine is unlikely to provide adequate control i.e.:

- The use of Balance® or newer grass herbicides such as Boxer Gold® and Sakura®.
- Use of group A herbicides post-emergent if herbicide resistance not present
- Inter-row cultivation is only an option in wide row systems
- Inter-row shielded sprayer (glyphosate) is only an option in wide row systems
- Crop topping or weed wiping are not options to prevent seed set of escape weeds.

Avoid paddocks with high seed numbers of herbicide resistance unless a programmed strategy is in place. [30]

Newer grass herbicides are now available, including Boxer Gold, Sakura. See www.apvma.gov for label information.

For more information on weed management, see Section 6: Weed Control.

1.5 Fallow chemical plant-back effects

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). 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. [31]

In wheat-chickpea rotations, adhere to label plant-back restrictions. Broadstrike®, Eclipse®, Lontrel®, metsulfuron are used in preceding crops in the Southern region, subject to plant-back time and rainfall requirements.

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

Rotational crop plant-back intervals for southern Australia

Where areas have received limited rain during the spring and summer months, there is potential for herbicide residues to still be present in the soil when sowing commences in autumn, unless there are mild temperatures and adequate moisture at least a month or more before sowing (Table 7).

Conditions required for breakdown

Warm, moist soils are required to break down most herbicides through the processes of microbial activity. For the soil microbes to be most active, they need good moisture and an optimum soil temperature range of 18°C to 30°C. Extreme temperatures above or below this range can adversely affect soil microbial activity and slow herbicide

30 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

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

MORE INFORMATION

Rotational crop plant-back intervals for southern Australia.

breakdown. Very dry soil also reduces breakdown. To make matters worse, where the soil profile is very dry it requires a lot of rain to maintain topsoil moisture for the microbes to be active for any length of time.

Risks

In those areas that do not experience conditions which will allow breakdown of residues until just prior to sowing, it is best to avoid planting a crop that is sensitive to the residues potentially present on the paddock, and opt for a crop that will not be affected by the suspected residues. In most cases, cereals or canola would be better options as these crops are comparatively less affected by herbicide residues. If dry areas do get rain and the temperatures become milder, then they are likely to need substantial rain (more than the label requirement) to wet the sub-soil, so the topsoil can remain moist for a week or more. This allows the microbes to be active in the top-soil where most of the herbicide residues will be found. Sensitive crops include legume pastures (e.g. clovers, Lucerne, or forage legumes) and pulse crops (eg. lentils, lupins, fieldpeas, faba beans, or vetch). [32]

Table 7: *Minimum re-cropping intervals and guidelines for common broadacre herbicides.*

Product	Rate	Plant-back period	Wheat	Barley	Oats	Canola	Legume Pasture	Pulse Crops
2,4-D Ester 680 *	0–510 ml/ha	(days)	1	1	1	14	7	7
	510–1,150 ml/ha		3	3	3	21	7	14
	1,150–1,590 ml/ha		7	7	7	28	10	21
Amicide Advance 700® *	0–500 ml/ha	(days)	1	1	1	14	7	7
	500–980 ml/ha		3	3	3	21	7	14
	980–1,500 ml/ha		7	7	7	28	10	21
Kamba® 500 *	200 ml/ha	(days)	1	1	1	7	7	7
	280 ml/ha		7	7	7	10	14	14
	560 ml/ha		14	14	14	14	21	21
Hammer 400® EC					No residual effects			
Nail 420 EC®					No residual effects			
Goal®					No residual effects			
Striker®					No residual effects			
Sharpen®	26 g/ha	(weeks)	-	-	-	16	-	-
Lontrel®	300 ml/ha	(weeks)	1	1	1	1	36	36
Garlon 600®		(weeks)	1	1	NS	NS	NS	NS
Allyv **		(weeks)	2	6	36	36	36	36
Logran® #		(months)	-	-	-	12	12	12
Gleanv **		(months)	-	9	6	12	12	12
Grazon Extra®/Grazon DS®		(months)	9	9	NS	9	24	24
Tordon 75D®, Tordon 242®		(months)	2	2	NS	4	9	6
Tordon Fallow Boss®		(months)	9	9	NS	12	20	20

* 15 mm rainfall required to commence plant-back period
** Period may extend where soil pH is greater than 7
\# Assumes 300 mm rainfall between chemical application and sowing
NS Not Specified

Source: RMS.

32 Dow AgroSciences. Rotational crop plant-back intervals for southern Australia. http://msdssearch.dow.com/PublishedLiteratureDAS/dh_0931/0901b80380931d5a.pdf?filepath=au&fromPage=GetDoc

1.5.1 Herbicide residues in soil

Residues from herbicides used in the current or previous crop could impact on subsequent crop choice in rotations (Photo 5). 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. Check herbicide history in paddocks for any chemical that may cause any detrimental effect to chickpeas. 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. [33]

Photo 5: *Herbicide residue affected plants appear pale and stunted.*

Source: DAFWA.

Herbicides such as group B's (Logran®, Glean®, Hussar® and Ally®) typically pose the greatest threat if they are persistent in the soil when chickpeas are planted. Typical symptoms are stunting and yellowing of the plants if affected. Other herbicides to be wary of are Lontrel™, Amine™ (used over summer) and Dicamba (used prior to

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

VIDEOS

12. GCTV16: Desi Chickpea – considering herbicide residuals.

cropping). These herbicides (group I's) can cause twisting and growth distortions of plants. [34]

For more information, see Section 6: Weed control.

1.6 Seedbed requirements

Preparation of a seedbed to ensure good seed soil contact is an important element in successful crop establishment. A firm, smooth seedbed with most of the previous crop residue incorporated is best. This will allow proper depth of planting as well as good seed-soil contact, which is essential for rapid germination and emergence. [35]

In other pulses (faba beans) in southern Australia, it is recommended that the previous crop stubble be heavily grazed, slashed, or burnt in order to obtain a flat seedbed. Rolling after seeding should be considered on stony or extremely cloddy soil, because pods set low on the plant may cause harvest difficulties. [36]

1.7 Soil moisture

1.7.1 Dryland

Chickpeas are deemed to require >350 mm annual rainfall, but there are opportunities to grow them in lower rainfall areas if adequate soil moisture is present at sowing (e.g. >20 mm of stored soil water at 0–60 cm depth). The best guide to assessing soil water storage is to put down several soil cores. [37]

Tillage

Photo 6: *The impact of tillage varies with the tillage implement used: inversion tillage using a mouldboard plough, as pictured here, results in greater impacts than using a chisel or disc plough.*

Source: GRDC.

Research from Qld found that one-time tillage with chisel or offset disc in long-term, no-tillage helped to control winter weeds, and slightly improved grain yields and profitability, while retaining many of the soil quality benefits of no-till farming systems (Photo 6). Tillage reduced soil moisture at most sites; however, this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received after tillage and prior to seeding and during the crop of that year. The occurrence of rain between the tillage and sowing or immediately after sowing

34 M Witney, GRDC. Update Papers. Chickpea management and agronomy. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/07/Chickpea-management-and-agronomy

35 https://hort.purdue.edu/newcrop/afcm/chickpea.html

36 Agriculture Victoria, 2013. Growing Faba Bean. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

37 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

is necessary to replenish soil water lost from the seed zone. This suggests the importance of timing of tillage and of considering the seasonal forecast. Future research will determine the best timing for strategic tillage in no-till systems (Photo 7). [38] Note that these results are from one season and research is ongoing, so any impacts are likely to vary with subsequent seasonal conditions.

Photo 7: *Strategic tillage can provide control for herbicide-resistant weeds and those that continue to shed seed throughout the year. Here it has been used for control of barnyard grass in fallow.*

Source: GRDC.

MORE INFORMATION

GRDC Strategic Tillage Tips and Tactics fact sheet.

Research in Spain found that conventional tillage practices led to better chickpea root development than no-tillage practices. [39]

1.7.2 Irrigation

Key points:

- Select fields with good layout and tail water drainage (Photo 8).
- Avoid high bulk density or high clay content soils that do not internally drain quickly.
- Avoid acid, saline, or sodic soils (see levels below).
- Pre-irrigate or water-up to fill the soil profile wherever possible.
- Irrigate early at 60–70% of field capacity to avoid crop stress and soil cracking open.

Full or supplementary irrigation of chickpea is common in northern Australia where chickpea is grown in rotation with other irrigated crops, such as cotton. Management requirements for irrigated chickpea are the same as for dryland, but their sensitivity to waterlogging, for even a short time, can result in severe losses, particularly if the crop is also under stress from herbicides or disease.

Using sprinkler irrigation equipment reduces the risk of waterlogging, even during flowering and pod-fill; however, there may be a higher risk of foliar disease, e.g. Botrytis grey mould and Ascochyta blight, due to the increased irrigation frequency and leaf wetness. [40]

Key tips for success

- **Drainage**: Ensure the layout allows irrigation and drainage within eight hours.

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

39 Muñoz-Romero, V., López-Bellido, L., & López-Bellido, R. J. (2012). The effects of the tillage system on chickpea root growth. *Field Crops Research*, *128*, 76-81.

40 Pulse Australia. 2015. Chickpea Production: Southern and Western Region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

- **Soil structure**: Good soil structure ensures good water infiltration, root penetration, and internal drainage.
- **Subsoil moisture**: Pre-irrigate or water-up to achieve adequate soil moisture for uniform emergence and during the vegetative stage. Irrigate prior to flowering to ensure a good profile of moisture during flowering and pod fill.
- **Sown on time**: Sow recommended varieties within the preferred sowing window for your location.
- **Crop establishment**: Use good quality seed and germination test retained seed (Photo 9). Aim for a plant population of 35 to 40 plants per square metre.
- **Adequate nutrition**: While chickpeas are efficient at extracting soil phosphorus, it is wise to apply adequate phosphorus relative to the paddock history and soil test results. Approximately 40 kg of P per hectare is required for a 4 tonne crop. Good inoculation procedures with the appropriate rhizobium should meet the N requirements of chickpeas; however, low zinc and sulfur levels should also be addressed.
- **Soil moisture**: Check soil moisture regularly to ensure timely irrigations to avoid stress or possible crop damage. Moisture monitoring equipment is now available at reasonable prices and can assist in more precise measuring, particularly at depth. Ensure plants do not stress during the reproductive stage and have adequate available soil water for the entire growing season. [41]

Photo 8: *Poor quality seed on the left—all seed was sown on the same day.*

Source: Pulse Australia.

41 Pulse Australia. Southern Pulse bulletin PA 2010 #17 – Irrigated chickpea management. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-irrigation.pdf

Photo 9: *Irrigated beds with damage from water remaining in the tail drain.*

Source: Pulse Australia.

Irrigated chickpea crops can be very profitable and rewarding with well managed crops yielding in excess of 3.5 t/ha. High yields have occurred across a wide range of soil types and irrigation layouts through a combination of correct paddock selection, precise irrigation scheduling and close attention to chickpea agronomy. In addition, chickpeas can contribute to crop rotations because of their ability to fix nitrogen and provide a disease and weed break for following cereal crops.

Full or supplementary irrigation of chickpea is common in districts where chickpea is grown in rotation with other irrigated crops, such as cotton. Management requirements for irrigated chickpea are the same as for dryland, but their sensitivity to waterlogging, for even a short time, can result in severe losses, particularly if the crop is also under stress from herbicides or disease. [42]

Irrigation requirement for chickpea has been found to coincide with flowering and seed development period. [43]

Factors to consider when planning for irrigated chickpea production include:

- Avoid heavy clay or dense soil types (bulk density >1.5) that do not drain freely and are subject to waterlogging.
- Select fields with an effective irrigation layout, such as beds or hills, and relatively good grades.
- A border-check layout that is steeper than 1:800 grade is suitable provided there are short runs on free draining soils that can be irrigated quickly and do not remain saturated.
- Rolling may be required to flatten the ridges left by press wheel furrows or to flatten clods.
- Irrigation can be used in activating and incorporating a number of pre-emergent herbicides.
- Pre-irrigate to fill the moisture profile prior to planting chickpea crops, unless there has already been sufficient rainfall. Watering up is most effective in bed,

42 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

43 Malhotra, R. S., Singh, K. B., & Saxena, M. C. (1997). Effect of Irrigation on Winter-Sown Chickpea in a Mediterranean Environment. *Journal of Agronomy and Crop Science*, *178*(4), 237-243.

row and sprinkler systems, but is not recommended for border-check layout unless soil moisture is insufficient to achieve a uniform germination.

- As a general rule, irrigation of the emerged crop should start early when there is a deficit of between 30–40 mm and around 60–70% field capacity. Schedule irrigation using soil moisture indicators rather than the crop growth stage.
- Time irrigation application to prevent moisture stress during flowering and podding and to reduce the impact of high temperatures on yield, quality and grain size. This is particularly important with large Kabuli types. Chickpeas are very sensitive to waterlogging during flowering and podding so great care is required to provide adequate soil moisture without causing waterlogging.
- In furrow irrigation systems, water every second row to avoid waterlogging. Doubling up the number of siphons can increase water flow and reduce irrigation time.
- Aim to have watering completed in less than eight hours, and have good tail water drainage to avoid any waterlogging in the crop area.
- Avoid irrigating if rain is forecast for the near future.
- In border-check layouts and paddocks with heavy soil types or long runs: if in doubt, do not water. [44]

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 can be based on 1 tonne grain per megalitre water supply (per hectare).

To offset the good performances, there are growers who have only achieved yields of 1.0–1.5 t/ha and some of the common causes have been:

- problems with poor crop establishment and vigour (seed quality, seedbed, herbicides)
- unsuitable soils limiting water extraction (sodic or saline subsoils)
- poor scheduling of in-crop irrigation
- restricted water supply limiting yield.

Chickpeas are very sensitive to waterlogging and even if waterlogged for a short period of time, crop losses can be severe. This has particularly occurred where crops have been moisture stressed, allowing soils to dry out to depth and often crack open (Photo 10).

Waterlogging is a stress on a chickpea crop and when combined with other stresses such as moisture stress, damaged root systems, disease, herbicide injury, or sodic and saline soils can be a disaster. Watering during flowering or podfill when the crop is more sensitive further increases the risk of yield loss. [45]

44 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

45 Pulse Australia. Southern Pulse bulletin PA 2010 #17 – Irrigated chickpea management. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-irrigation.pdf

Photo 10: *Chickpea on the left received a very late irrigation.*

Source: Pulse Australia.

Irrigation management strategy for chickpea

- Pre-irrigate to fill the moisture profile prior to planting chickpea crops, unless there has already been sufficient rainfall. Watering up is most effective in bed, row and sprinkler systems, but is not recommended for border-check layout unless soil moisture is insufficient to achieve a uniform germination. Ensure that seed placement allows at least 7 cm of soil above the seed if using Balance® or simazine and the soil surface is left flat to prevent herbicide leaching into the plant furrow.
- As a general rule, irrigation of the emerged crop should start early when there is a deficit of between 30–40 mm and around 60–70% field capacity. Schedule irrigation using soil moisture indicators rather than the crop growth stage.
- Time irrigation application to prevent moisture stress during flowering and podding and to reduce the impact of high temperatures on yield, quality and grain size. This is particularly important with large Kabuli types. Chickpeas are very sensitive to waterlogging during flowering and podding, so great care is required to provide adequate soil moisture without causing waterlogging.
- In furrow irrigation systems, water every second row to avoid waterlogging. Doubling up the number of siphons can increase water flow and reduce irrigation time.
- Aim to have watering completed in less than eight hours, and have good tail water drainage to avoid any waterlogging in the crop area.
- Avoid irrigating if rain is forecast for the near future.
- In border-check layouts and paddocks with heavy soil types or long runs: if in doubt, do not water. [46]

Sowing rate and row spacing

In southern NSW the target density is 35–45 plants/m^2. Adjust sowing rates to take account of seed size, germination percentage, and establishment conditions. In southern NSW, irrigation growers have sown at up to 90 cm row spacing on beds (Photo 11) without a significant yield penalty and has also allowed the use of shielded sprayers.

46 Pulses Australia. Chickpea Production: Southern and Western regions. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Photo 11: *Chickpea on irrigated beds with 90 cm row spacing.*

Source: Pulse Australia.

Irrigation techniques to reduce the period of waterlogging

- For furrow irrigation, water every second row.
- Doubling up siphons to speed up water flow.
- Do not irrigate if there is likelihood of rain.
- Ensure that tail water drains away quickly.

MORE INFORMATION

Irrigated Chickpeas – Best Practice Guide.

Spray irrigation

The risk of waterlogging is significantly reduced when using lateral move or centre pivot irrigators compared to flood as the amount and timing of water application can be better controlled. However wet foliage from more frequent irrigations can increase the risk of fungal diseases—particularly Ascochyta blight and Botrytis grey mould. Greater attention to disease management, and monitoring variety chosen in relation to disease resistance is important. [47]

1.8 Yield and targets

Seed yields of chickpea are low (world average 623 kg ha-1), compared to many other crops. Early field trials indicate that seed yield in chickpea is controlled by the Harvest Index of branches and that seed yields might be raised by restricting branches in high density stands to no more than two, each with a high harvest index. [48]

Starting soil water can also have a strong influence on the yield expectation of chickpea as well as the riskiness of production.

The most accurate prediction of a variety's performance is a stable yield in many locations over several years.

Yield results from Pulse Breeding Australia (PBA) and National Variety Trials (NVT) are available from the NVT website, as well from the specific Pulse Variety Management Package (VMP) brochure. Long term yields can be represented in several different ways but are typically displayed as either site specific, averaged over multiple years (Figure 4), or for each year averaged over multiple sites for a region. All trial sites are disease free.

Results lists are approximates for the following varieties (ordered from highest t/ha to lowest).

47 Pulse Australia. Southern Pulse bulletin PA 2010 #17 – Irrigated chickpea management. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-irrigation.pdf

48 K.H.M. Siddique and A.M. Sedgley. An ideotype for chickpea (*Cicer arietinum* L.) in a dry mediterranean environment. 2nd Aust. Agron Conf.©,Uni of WA.

Figure 4: *Yield group (t/ha) for Desi Chickpea (top) and Kabuli chickpea (bottom) in the Southern region (SA, Vic) between 2012-2016. Yield Group: Presents data on half tonne yield intervals based on trials that match the yield range from across all years.*

Source: NVT Online

IN FOCUS

1.8.1 Critical period for chickpea yield

Crop species have their own characteristic 'window' of development when yield is more vulnerable to stresses such as drought, nutrient deficiency, frost and heatwaves.

To determine the critical window for chickpea yield, the South Australian Research and Development Institute (SARDI) set up trials at Roseworthy (sowing date 7 June) and Turretfield (sowing dates 14 June and 9 July) in South Australia.

Crops of PBA Boundary⁽ᵈ⁾ and PBA Slasher⁽ᵈ⁾ were shaded for two weeks at different stages during the growing season. Untreated controls yielded three tonnes per hectare.

The trials showed that the critical window for chickpeas starts at about 300 'degree-days' before flowering and the most vulnerable stage for yield was found to be 200 'degree-days' after flowering.

Degree-days are a calculation of time based on daily temperature and are necessary to account for the fact that crops develop faster at high temperatures. For the crop, one day at 15°C is not the same as a day at 10°C.

For example, if chickpeas are grown in conditions where the daily mean temperature is 15°C, the critical stage of 200 degree-days will be reached 13 days after flowering (200 ÷ 15 = 13). If chickpeas are grown in a warmer region or the crop was sown late with, for example, a daily mean temperature of 20°C, the crop will reach the 200-degree-days mark 10 days after flowering (200 ÷ 20 = 10).

Ensuring good growing conditions (sufficient supply of water and nutrients) and avoiding stress (such as frost and heat) during the critical window are essential for high-yielding chickpea crops. [49]

MORE INFORMATION

L Lake, V Sandras. SARDI. (Nov – Dec 2014). Ground Cover issue 113: Critical period for chickpea yield.

1.8.2 Seasonal outlook

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

Before planting, identify the target yield in grain, hay or DM required to be profitable:

- Do a simple calculation to see how much water you need to achieve this yield.
- Know how much soil water you have (treat this water like money in the bank).
- Think about how much risk your farm can take.
- Consider how this crop fits into your cropping plan—will the longer-term benefits to the system outweigh any short-term losses?
- Avoiding a failed crop saves money now and saves stored water for future crops. [50]

Mobile applications (apps) are available for decision support, providing tools for ground-truthing precision agriculture data. Apps and mobile devices are making it easier to collect and record data on-farm. The app market for agriculture is evolving rapidly, with new apps becoming available on a regular basis. For more information, download the GRDC Update paper, Managing data on the modern farm. [51]

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. [52]

Australian CliMate

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

49 L Lake, V Sandras. SARDI. (Nov – Dec 2014). Ground Cover issue 113: Critical period for chickpea yield. https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-113-NovDec-2014/Critical-period-for-chickpea-yield

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

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

52 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

One of the CliMate tools, *Season's progress?*, uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. It explores the readily available weather data, compares the current season with the long-term average, and graphically presents the spread of experience from previous seasons. Crop progress and expectations are influenced by rainfall, temperature and radiation since planting. *Season's progress?* provides an objective assessment based on long-term records:

- How is the crop developing compared to previous seasons, based on heat sum?
- Is there any reason why my crop is not doing as well as usual because of below average rainfall or radiation?
- Based on the 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.

1.8.3 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.

Crop yield is highly influenced by fallow rainfall storage and soil moisture at sowing. A high frequency of low-yielding crops with small margins may be less profitable than a well-planned rotation which includes some crops grown on long fallow.

Good farming systems take into account soil health, stubble cover, and fallow management to reduce runoff and evaporation, thereby storing as much soil moisture as possible. A small amount of extra soil stored moisture can go close to doubling crop profitability.

Extra soil water storage can double profit.

An extra 20 mm of soil stored water could add 400 kg/ha to yield—enough to double the profit in some situations! Soil moisture storage improves with soil health, which is about building soil organic matter with plenty of earthworms. This can be destroyed by tillage, compaction, or low soil cover. Controlled traffic in combination with zero tillage improves infiltration, which results in less runoff and more even moisture storage across a paddock. Good soil structure can also reduce waterlogging and its effect on crop yield and nitrogen losses. [53]

1.8.4 Water Use Efficiency

Water Use Efficiency (WUE) is the measure of a cropping system's capacity to convert water into plant biomass or grain (Figure 6). It includes both the use of water stored in the soil and rainfall during the growing season.

- WUE 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

53 Fritsch S, Wylie P. GRDC Update Papers. 2015. Finding more yield and profit from your farming system. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Finding-more-yield-and-profit-from-your-farming-system

- the crop's ability to convert biomass into grain (harvest index). [54]

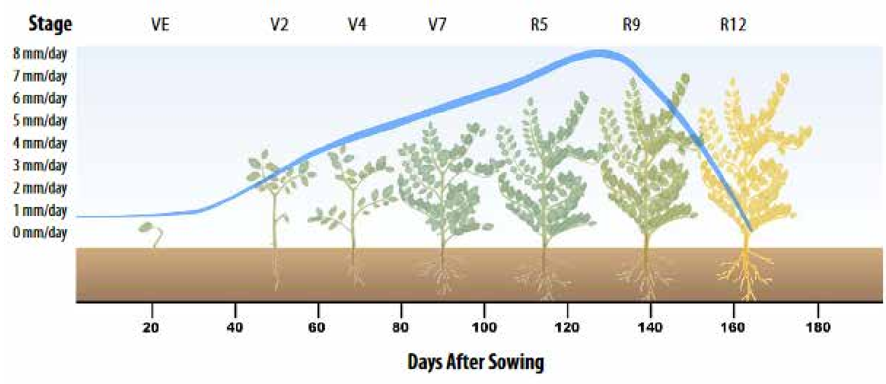


Figure 5: *Average daily water use pattern for chickpea at critical growth stages. NOTE: information based on research in the Northern region.*

Source: WATERpak.

The strongest determinant of chickpea grain yield and its water use under rainfed conditions is rainfall and its distribution. Water availability is a major constraint for production of grain in Australia and improving WUE is a primary target for growers, breeders, and agronomists. WUE benchmarks can be used to derive attainable yield for a location and season.

Seasonality and size of rainfall events also influence crop WUE. In the southern and western growing regions, rainfall is winter-dominant, falling during the crop's growing season. Soil evaporation, favoured by winter rainfall and small events, is the main unproductive source of water loss in southern and western regions. Collectively, vapour pressure deficit and rainfall patterns are the main climate determinants of location-specific WUE. [55]

Large inter-seasonal fluctuations in weather can result in larger inter-seasonal fluctuations in water use, and therefore in production of legumes. Seasonal evapotranspiration (ET) has been found to significantly correlate with seasonal rainfall for chickpeas.

Potential transpiration efficiencies (TE) of 15 kg/ha−1 mm−1 , together with soil evaporation (Es) values of 100–125 mm can be used as benchmark values to assess the yield potential of cool season grain legume crops in low rainfall Mediterranean-type environments. [56]

Research conducted in a Mediterranean-type environment investigated the effect of supplemental irrigation and sowing date on yield and WUE in winter-sown chickpea. Limited supplemental irrigation can play a major role in boosting and stabilizing the productivity of winter-sown chickpea. Four levels of supplemental irrigation (SI) were implemented as treatments: full SI, 2/3 SI, 1/3 SI, and no SI; i.e. rainfed. The results showed that chickpea yield per unit area increases with both earlier sowing and increased SI. However, WUE under supplemental irrigation decreases with earlier sowing, due to the relatively large increase that occurs in the amount of evapotranspiration at early sowing dates. The 2/3 Supplemental irrigation level was found to give the optimum Water Use Efficiency for chickpea. [57]

Nitrogen-deficient soils will also reduce WUE, leading to impaired photosynthesis and a drop in above-ground dry matter per unit transpiration.

VIDEOS

13. GCTV12: Water Use Efficiency Initiative.

54 GRDC. (2009). Water Use Efficiency – Fact Sheet. Northern Region.

55 V Sandras, G McDonald. GRDC. (2012). Water Use Efficiency of grain crops in Australia: principles, benchmarks and management.

56 Siddique, K. H. M., Regan, K. L., Tennant, D., & Thomson, B. D. (2001). Water use and Water Use Efficiency of cool season grain legumes in low rainfall Mediterranean-type environments. *European Journal of Agronomy*, *15*(4), 267-280.

57 Oweis, T., Hachum, A., & Pala, M. (2004). Water Use Efficiency of winter-sown chickpea under supplemental irrigation in a Mediterranean environment. *Agricultural water management*, *66*(2), 163-179.

IN FOCUS

Chickpea Water Use Efficiency in relation to cropping system, cultivar, soil nitrogen and Rhizobial inoculation in semiarid environments

In this research, cropping system, cultivar, and inoculation all had greater impact on WUE than on the amount of water extracted by the crop from the soil. Crops grown in semiarid rainfed conditions are prone to water stress, which could be alleviated by improving cultural practices. This study determined the effect of cropping system, cultivar, soil nitrogen status and *Rhizobium* inoculation (*Rz*) on water use and Water Use Efficiency (WUE) of chickpea (*Cicer arietinum* L.) in semiarid environments.

Four varieties were grown in no-till barley, no-till wheat, and tilled-fallow systems and under various rates of N fertiliser (0, 28, 56, 84, and 112 kg N ha–1) coupled with or without *Rz*. On average, chickpea used about 10 mm of water from the top 0–15 cm soil depth. In the tilled-fallow system, chickpea extracted 20% more water in the 15–30 cm depth, 70% more in the 30–60 cm depth, and 156% more in the 60–120 cm depth than when it was grown in the no-till systems. Cropping system, cultivar, and inoculation all had greater impact on WUE than on the amount of water extracted by the crop from the soil. The improvement of cultural practices to promote general plant health along with the development of cultivars with improved crop yields will be keys for improving WUE of chickpea in semiarid environments. e 30–60 cm depth, and 156% more in the 60–120 cm depth than when it was grown in the no-till systems.

WUE increased from 4.7 to 6.8 kg ha–1 mm–1 as N fertiliser rate was increased from 0 to 112 kg N ha–1 when chickpea was grown in the no-till barley or wheat systems, but chickpea grown in the tilled-fallow system did not respond to changes in the fertiliser N rates averaging WUE of 6.5 kg ha–1 mm–1. In the absence of N fertiliser, the application of *Rz* increased WUE by 33% for chickpea grown in the no-till barley system, 30% in the no-till wheat system, and 9% in the tilled-fallow system. Chickpea inoculated with *Rhizobium* achieved a WUE value similar to the crop fertilised at 84 kg N ha–1. Without the use of *Rz*, chickpea increased WUE in a linear fashion with increasing fertiliser N rates from 0 to 84 kg N ha–1.

The improvement of cultural practices to promote general plant health along with the development of cultivars with improved crop yields will be keys for improving WUE of chickpea in semiarid environments. [58]

MORE INFORMATION

Gan, Y. T., Warkentin, T. D., Bing, D. J., Stevenson, F. C., & McDonald, C. L. (2010). Chickpea Water Use Efficiency in relation to cropping system, cultivar, soil nitrogen and Rhizobial inoculation in semiarid environments. *Agricultural water management*, 97(9), 1375-1381. *97*(9), 1375-1381.

Crop biomass and grain yield depend on photosynthesis. Photosynthesis involves the uptake of carbon dioxide (CO_2) through stomata, which are pore-like, specialised cells in the surface of leaves. However, open stomata required for CO_2 uptake are an open gate for water loss. Therefore, there is a tight trade-off between uptake of CO_2 and water loss, and this explains the close link between crop production and water use. [59]

58 Gan, Y. T., Warkentin, T. D., Bing, D. J., Stevenson, F. C., & McDonald, C. L. (2010). Chickpea Water Use Efficiency in relation to cropping system, cultivar, soil nitrogen and Rhizobial inoculation in semiarid environments. *Agricultural water management*, *97*(9), 1375-1381.

59 V Sandras, G McDonald. GRDC. (2012). Water Use Efficiency of grain crops in Australia: principles, benchmarks and management.

Managing to optimise Water Use Efficiency

Measures to improve WUE should aim to reduce soil evaporation during winter both directly, by increasing soil cover, for example, by mulches or earlier-developing canopies, and indirectly by increasing infiltration. In spring, measures to increase WUE should aim at reducing transpiration by minimising canopy development to what is required by the crop to maximize harvest index. [60]

While farmers have no control over rainfall, by using different management practices they can affect how much of the rainfall is used by the crop and how efficiently it is used.

Fallowing captures out-of-season rainfall and can increase the amount of water available for crop growth. However, the proportion of rainfall retained by fallowing (also referred to as fallow efficiency) can be small, typically of the order of 20% but frequently less.

Retaining stubbles on the fallow and controlling summer weeds may help to reduce water loss from the fallow and improve fallow efficiency, although the value of stubble retention appears to vary with soil texture and rainfall. On sandy soils, there may be little benefit from stubble retention on water capture over summer and in some cases standing stubble may enhance evaporative losses. In contrast, on clay soils in southern Australia, fallow efficiencies up to 40% have been measured with retained stubbles.

Crop choice: There are intrinsic differences in the WUE of crops, with wheat more water use efficient than grain legumes, or canola whether considered in terms of total biomass production or grain yield. Chickpeas in the Australian Mediterranean–type environment have been estimated to have a WUE based on total biomass of 16.0 (11.1–18.3) kg/ha.mm and based on grain yield of 6.2 (4.7–8.9) kg/ha.mm. [61]

Arguably, time of sowing is the most important management practice determining WUE and yield. Many studies in a range of crops have shown that 'late' sowing will reduce yields, although for short-season varieties, sowing very early may have little benefit or may reduce yields. Time of sowing generally has only a small effect on total crop water use but can have a marked effect on WUE, and the highest water use efficiencies are consistently achieved when the crop is sown at the optimum time. Late sowing reduces WUE for a number of reasons: sowing into colder soil delays crop establishment and early vigour, which increases the proportion of crop evapotranspiration lost as soil evaporation; there is a higher likelihood of heat stress around flowering and during grain growth; and there are reductions in biomass per unit water use associated with increasing vapour pressure deficit.

Recommendations for increasing water use in crop have been made based on trials exploring water use of chickpeas in Southern Australia (Table 8). Measures to improve WUE should aim to reduce soil evaporation during winter both directly, by increasing soil cover, for example, by mulches or earlier-developing canopies, and indirectly by increasing infiltration. In spring, measures to improve WUE should aim at reducing transpiration by minimising canopy development to what is required by the crop to maximise harvest index.

VIDEOS

14. GRDCTV10: Grazing stubbles and Water Use Efficiency.

60 Siddique, K. H. M., & Sedgley, R. H. (1987). Canopy development modifies the water economy of chickpea (*Cicer arietinum* L.) in south-western Australia. *Crop and Pasture Science*, *37*(6), 599-610.

61 Siddique, K. H. M., Regan, K. L., Tennant, D., & Thomson, B. D. (2001). Water use and Water Use Efficiency of cool season grain legumes in low rainfall Mediterranean-type environments. *European Journal of Agronomy*, *15*(4), 267-280.

Table 8: *Effect of planting date on total water use (E,) and WUE of chickpea.* [62]

Planting date	Total water use (E_t mm)	WUE (kg dry matter ha^{-1} mm^{-1})	GWUF. (kg seed ha^{-1} mm^{-1})	Planting date	Total water use (E_1 mm)	WUE (kg dry matter ha^{-1} mm^{-1})	GWUE (kg seed ha^{-1} mm^{-1})
(a) 1982				**(b) 1983**			
11 May (D1)	213.2	23.2	6.81	17 May (D1)	191.8	35.2	6.52
26 May (D2)	214.1	19.5	5.94	31 May (D2)	182.8	29.2	6.18
17 June (D3)	229.6	18.8	5.55	14 June (D3)	182.1	26.6	6.15
30 June (D4)	227.2	16.9	4.86	30 June (D4)	188.3	21.1	5.88
				20 July (D5)	182.1	17.7	5.15
Mean	221.0	19.5	5.79	Mean	185.4	26.2	5.98
l.s.d. (P<0.5)	24.8	2.5	1.09	l.s.d. (P<0.5)	17.8	5.8	1.04
C.V. (%)	7.0	10.2	11.7	C.V. (%)	6.2	12.8	11.3

Source: Siddique *et al*

MORE INFORMATION

Water Use Efficiency of grain crops in Australia: principles, benchmarks and management

VIDEOS

15. Over The Fence South: Weighing up water efficiency versus wide rows

The spatial arrangement of plants in crops, the result of the chosen row spacing and sowing rate, affects crop water use in two main ways: firstly it affects the rate of early growth and the degree and timing of canopy closure, and thus the proportion of crop water use lost as soil evaporation; and secondly it influences the partitioning of water use between the pre-anthesis and post anthesis periods. The amount and distribution of rainfall will largely influence the optimum sowing rate.

Nevertheless, grain yields (and WUE) are quite stable over a wide range of sowing rates (Table 8), which affords a degree of flexibility when deciding on the most appropriate sowing rate. Increased sowing rates increase early crop growth rate and potentially reduce evaporation from the soil surface, thus 'saving' water for use later in the season. On the other hand, high sowing rates will lead to vigorous early crop growth and water use, which may cause early depletion of soil moisture if rainfall is low. In general, using low plant densities in low-rainfall regions, or in regions where crops depend on soil moisture reserves at sowing, helps to partition water use between the pre-flowering and post-flowering periods more effectively.

Row spacing may have relatively little effect on WUE. The potential gains in WUE from altering row spacing will depend on how it affects the proportion of moisture lost from bare soil evaporation and how it influences the pattern of water use during the growing season. Increased row spacing can lead to increased exposure of the soil surface and raised soil evaporation, but where the maximum leaf area of the crop is small, or where the soil surface is not moist for long periods of time, altering row width has little effect on bare soil evaporation. Present evidence suggests that using wide rows in non-cereal crops may have limited benefit to the efficient use of seasonal rainfall or may cause reductions in efficiency. [63]

1.8.5 Nitrogen use efficiency

Nitrogen Use Efficiency (NUE) is the product of absorption efficiency (amount of absorbed N/quantity of available N) and the utilisation efficiency (yield/absorbed N). For a large number of crops, there is a genetic variability for both N absorption efficiency and for N utilisation efficiency. For abiotic stress improvement in crops, NUE has become the second priority after drought both in the private and in the public sector.

One of the main challenges in the future will be to develop reliable decision support systems with the help of sensors and biological diagnostic tools in precision

62 Siddique, K. H. M., & Sedgley, R. H. (1987). Canopy development modifies the water economy of chickpea (*Cicer arietinum* L.) in south-western Australia. *Crop and Pasture Science*, *37*(6), 599-610.

63 V Sandras, G McDonald. GRDC. (2012). Water Use Efficiency of grain crops in Australia: principles, benchmarks and management.

agriculture, in order to optimise the application of N under organic or conventional conditions in a more sustainable manner. [64]

Breeding for more efficient symbioses with Rhizobia and arbuscular mycorrhizal (AM) fungi can be an alternative for increasing plant productivity, while using the same amount of synthetic N fertiliser. Conservation tillage using no till and continuous cover cropping cultures are also known to increase significantly the potentiality and diversity of plant colonisation by AM fungi in comparison to conventional tillage. Thus, these new alternative farming techniques can increase NUE for a number of crops through the beneficial action of AM.

Under both humid conditions and dry weather, chickpea has been found to maintain a constant partial factor N use efficiency (PFNUE: grain yield per unit fertiliser N) and a consistently high N utilisation efficiency (NUtE: grain yield per unit N in the above-ground dry matter) for grain production. [65]

Whatever the mode of N fertilisation, an increased knowledge of the mechanisms controlling plant N economy is essential for improving NUE and for reducing excessive input of fertilisers, while maintaining an acceptable yield and sufficient profit margin for farmers.

There are now sufficient data from Australian and overseas studies to be able to categorise the pulses either as strong N_2 fixers (lupin and fababean), medium N_2 fixers (chickpea, field pea, mung bean and lentil) or weak N_2 fixers (navy bean).

MORE INFORMATION

Water Use Efficiency of grain crops in Australia: principles, benchmarks and management

Nitrogen Fixation Benefits of Pulse Crops

https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2009/09/nitrogen-fixation-benefits-of-pulse-crops

1.9 Disease status of 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. 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. [66]

Ascochyta blight in chickpeas is now manageable, but can still loom as the biggest potential issue in Australian chickpea production unless it is managed by a combination of variety choice, strategic use of fungicides and crop hygiene (seed source, rotation, proximity of chickpea stubbles).

Chickpea crops in southern Australia and isolated parts of northern Australia are being hit by a more virulent strain of the damaging ascochyta blight.

Ascochyta resistant varieties are not immune to Ascochyta blight, particularly at pod fill, but do make it easier to control with reduced risk, inputs and expense. Lower rainfall areas must be considered as being at least medium risk for ascochyta, but could be high risk on an individual paddock basis. Know the Ascochyta blight disease rating of the variety grown; assess the individual paddock risk and manage the crop appropriately. Be aware of the specific management needs for the variety chosen through its variety management package (VMP).

Avoid sowing chickpeas into paddocks that have a recent and prolonged history of predominantly legume (e.g. medic, lentil, and field pea) or broadleaf crops (e.g. canola). Phoma, fusarium, pythium, or sclerotinia may be present.

64 Hirel, B., Tétu, T., Lea, P. J., & Dubois, F. (2011). Improving nitrogen use efficiency in crops for sustainable agriculture. *Sustainability*, *3*(9), 1452-1485.

65 Neugschwandtner, R. W., Wagentristl, H., & Kaul, H. P. (2015). Nitrogen yield and nitrogen use of chickpea compared to pea, barley and oat in Central Europe. *International Journal of Plant Production*, *9*(2), 291-304.

66 GRDC (2011) What to consider before planting chickpeas. GRDC Media Centre 6 June 2011

Seed treatment should be considered mandatory for protection, especially with Kabuli types. Resistance to PRR may perhaps provide slightly better tolerance to waterlogging or common root rots. [67]

1.9.1 Cropping history effects

Paddocks closer than 1 km to last year's chickpea stubble should be considered as a higher risk from Ascochyta blight infection and need to be managed as such. Varieties with higher Ascochyta resistance such as should be considered; otherwise, there is the need for programmed Ascochyta spraying through the season. Where possible place as great a distance as practical between this year and last year's chickpea paddocks and be mindful of common wind direction. [68]

For more information, see Section 9: Diseases.

1.10 Nematode status of paddock

Cereal Cyst Nematode (CCN, *Heterodera avenae*) is a pest of graminaceous crops worldwide. This nematode is a significant problem across south-eastern Australia. CCN becomes more problematic in areas where intensive cereal cropping occurs. Cereal cyst nematode will only infect, feed and develop on cereals and other grasses. Non-cereal crops, including chickpeas, will not host the nematode, so are useful in rotations to limit damage caused to cereals. [69]

Root Lesion Nematodes (RLN) are widespread in cropping soils. Although mainly considered an issue in wheat crops, RLN also infects chickpeas, with yield losses of 20–30% previously recorded in intolerant varieties. Chickpeas are susceptible to RLN, which means that this nematode colonises the root systems and builds up numbers in the soil. However, chickpea varieties can vary in their levels of resistance to RLN; this is related to the extent to which they build up RLN 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 RLN population left in the soil following chickpeas, the greater is the potential for a negative impact on the yield of subsequent crops.

1.10.1 Effects of cropping history on nematode status

Nematode numbers build up steadily under susceptible crops and cause decreasing yields over several years. Yield losses >50% can occur in some wheat varieties due to RLNs, 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 2 RLN species/g soil anywhere in the soil profile has the potential to reduce the grain yield of intolerant varieties. A tolerant crop yields well when high populations of nematodes are present (the opposite is intolerance). A resistant crop does not allow nematodes 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 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 nematodes is regularly updated in grower and planting

67 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

68 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

69 Soilquality.org. (2016). Cereal cyst nematode. http://www.soilquality.org.au/factsheets/cereal-cyst-nematode

MORE INFORMATION

Some recent research papers are available online:

Rhizoctonia solani AG8: New breakthroughs in control and management, 2015 Crop Updates paper

Liquid banding of fungicide increases yields of cereals in paddocks with rhizoctonia bare-patch, 2014 Crop Updates paper

Rhizoctonia bare patch in cereals - Integrated disease management options, 2013 Crop Updates paper

Root lesion nematode has a picnic in 2013, 2014 Crop Updates paper

Pratylenchus teres - WA's home grown Root Lesion Nematode, 2013 Crop Updates paper

For further information refer to Root lesion and burrowing nematodes: diagnosis and management.

guides. Note that crops and varieties have different levels of tolerance and resistance to different nematode species. [70]

For more information, see Section 8: Nematodes.

1.11 Testing soil for disease and nematodes

Diseases and nematodes that occur underground can be difficult to detect and diagnose but they must be identified correctly to enable appropriate control measures to be implemented. It is important to have paddocks diagnosed for plant parasitic nematodes and disease so that optimal management strategies can be implemented. Testing your farm will tell you if nematodes or disease are present in your paddocks and at what density as well as 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.

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. [71]

Root diseases that are most likely to be encountered under intensive cereal cropping systems are rhizoctonia bare patch, root lesion nematode, take-all, fusarium crown rot, cereal cyst nematode, common root rot, and pythium root rot.

Diseases caused by pathogenic micro-organisms can significantly reduce the yield of cereals. The most prevalent root diseases of cereals in southern Australia are rhizoctonia bare patch, root lesion nematode, fusarium crown rot, and take-all. Less widespread are cereal cyst nematode, common root rot, and pythium root rot.

It is crucial that these diseases are correctly diagnosed to enable the right control measures to be employed for the benefit of crop yields.

1.11.1 Soil and plant testing services for diagnosing root diseases

Firstly, look at the distribution of symptomatic plants throughout the whole crop.

To determine whether a fungal or nematode root disease is affecting a cereal crop, look for patchy areas of poor crop development associated with localised disease build up. Some root disease such as fusarium crown rot may be more evenly scattered or distributed throughout the crop.

Next, carefully dig up samples of apparently diseased as well as healthy plants.

Thoroughly wash the soil from the roots and examine them for indicative symptoms, which vary to some extent depending on the disease. Unthrifty plants may have smaller root mass, fewer root branches, root browning, root clumping, or damaged root tips (spear tips) compared to thrifty or well grown plants nearby.

The MyCrop app may assist you with diagnosis.

70 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

71 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

Confirmation of diagnosis

Suspected root disease or nematode problems in-crop can be confirmed by laboratory analysis of soil and/or roots. For patch diseases, sample from the edge of the patch rather than the centre.

Pre-season assessment:

The risk of root diseases being present in a paddock at a yield limiting level next season can be determined by paddock history and paddock monitoring in spring or soil tests. A review of paddock history will identify the diseases likely to be present in each paddock. The level of disease likely to develop can be determined by digging up plants in spring from areas of poor growth and examining the roots for symptoms.

An informed decision can be made about the future use of each paddock based on the presence or absence of a disease and the conduciveness of the current season and crop to further develop that disease.

Pre-season soil tests can be used where the paddock history is not adequate for planning future use. Soil tests are conducted on representative soil samples. PreDicta-B™ uses DNA assessment to determine the root diseases or nematode species present and the likely risk of crop damage. Test kits are available through accredited agronomists and resellers. [72]

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 Australia and includes tests for:

- cereal cyst nematode (CCN)
- take-all (*Gaeumannomyces graminis* var. *tritici* (Ggt) and *G. graminis* var. *avenae* (Gga))
- rhizoctonia barepatch (*Rhizoctonia solani* AG8)
- crown rot (*Fusarium pseudograminearum*) *Note that oats are not very susceptible to crown rot – but does host it.
- root lesion nematode (*Pratylenchus neglectus* and *P. thornei*)
- stem nematode (*Ditylenchus dipsaci*).

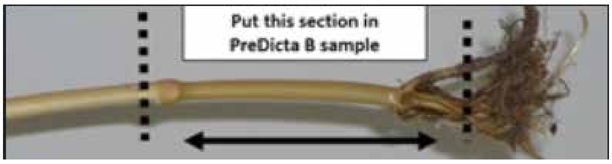


Photo 12: *Correct sampling strategy.*

Source: GRDC.

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.

1.12 Insect status of paddock

Deciding the best way to sample for a particular pest depends on where in the crop the pest feeds and shelters, and the effects of weather on its behaviour. The stage of crop development and the insect being monitored will determine which sampling method is most suitable. For example, pests in seedling crops generally cannot be collected by sweeping because the crop is too short.

Pest outbreaks occur often in response to natural conditions, but sometimes in response to management practices. Minimum tillage and stubble retention have

MORE INFORMATION

PIR SA Predicta B website

72 DAFWA (2016). Root disease under intensive cereal production systems. https://www.agric.wa.gov.au/barley/root-disease-under-intensive-cereal-production-systems

resulted in greater diversity of invertebrate species seen in crops. Cultural control methods such as burning, rolling, or cultivating stubbles are sometimes needed to complement chemical and biological controls. [73]

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

Soil insects include:

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

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

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

Soil insect control measures are normally applied at sowing. Since different insects require different control measures, the species of soil insects must be identified before planting. Soil insects are often difficult to detect as they hide under trash or in the soil. Immature insects such as false wireworm larvae are usually found at the moist/dry soil interface.

1.12.1 Insect sampling of soil

Sampling methods should be applied in a consistent manner between paddocks and sampling occasions. Any differences can then be confidently attributed to changes in the insect populations, and not different sampling techniques. [74]

Soil sampling by spade

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

Germinating-seed bait technique

Immediately following planting rain:

1. Soak insecticide-free crop seed in water for at least two hours to initiate germination.
2. Bury a dessertspoon of the seed under 1 cm of soil at each corner of a 5 m by 5 m square at five widely spaced sites per 100 ha.
3. Mark the position of the seed baits, as large populations of soil insects can destroy the baits.
4. One day after seedling emergence, dig up the plants and count the insects.

73 https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests

74 http://ipmguidelinesforgrains.com.au/insectopedia/introduction/sampling.htm

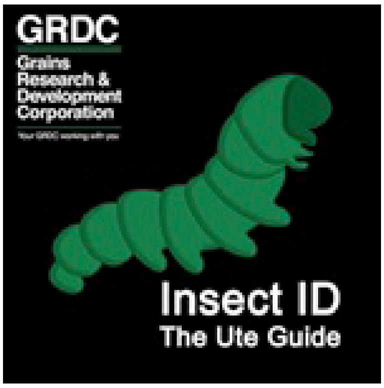
Trials have shown no difference in the type of seed used for attracting soil-dwelling insects. However, use of the type of seed to be sown as a crop is likely to indicate the species of pests that could damage that crop. The major disadvantage of the germinating-grain bait method is the delay between the seed placement and assessment. [75]

The South Australian Research and Development Institute (SARDI) Entomology Unit provides an insect identification and advisory service. The Unit identifies insects to the highest taxonomic level for species where this is possible and can also give farmers biological information and guidelines for control. [76]

PestNotes

PestNotes are designed specifically for growers, agronomists and farm advisers. They bring together the best available information and images on more than 50 invertebrate pests of the southern cropping region. These information sheets have been developed through a collaboration between cesar and the South Australian Research and Development Institute.

Insect ID: The Ute Guide



The Insect ID Ute Guide is a comprehensive reference guide for insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control them. Photos have been provided for multiple life-cycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored, and other pests that they may be confused with. Use of this app should result in better management of pests, increased farm profitability, and improved chemical usage. [77]

App Features:

- Region selection
- Predictive search by common and scientific names
- Compare photos of insects side by side with insects in the app
- Identify beneficial predators and parasites of insect pests
- Opt to download content updates in-app to ensure you're aware of the latest pests affecting crops for each region
- Ensure awareness of international bio-security pests

Insect ID, The Ute Guide is available on Android and iPhone.

It is important to consider paddock history when planning for pest management. Resident pests can be easier to predict by using paddock history and agronomic and weather data to determine the likely presence (and numbers) of certain pests

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

76 http://pir.sa.gov.au/research/research_specialties/sustainable_systems/entomology/insect_diagnostic_service

77 https://grdc.com.au/Resources/Apps

MORE INFORMATION

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within a paddock. This will point towards the likely pest issues and allow growers to implement preventative options. [78]

Reduced tillage and increased stubble retention have changed the cropping landscape with respect to soil moisture retention, groundcover, and soil biology and this has also affected the abundance and types of invertebrate species being seen in crops. These systems increase invertebrate biodiversity but also create more favourable conditions for many pests such as slugs, earwigs, weevils, beetles, and many caterpillars. In turn they have also influenced beneficial species such as carabid and lady beetles, hoverflies, and parasitic wasps. [79]

See Section 7: Insect control for more information.

78 https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-117-July-August-2015/Growers-chase-pest-control-answers

79 https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests