SECTION 1

Planning and paddock preparation

More information

[GRDC Update Papers: Barley agronomy in southern NSW]

1.1 Agronomy tips at a glance

- Plant barley as early as possible in the recommended window.
- Plant into good moisture conditions.
- Aim for a plant population of 100–120 plants/m^2, depending on variety and rainfall zone.
- Use good-quality, treated planting seed.
- Use soil testing and fertilise to achieve protein of 10–11% (dry basis).
- Malting barley requires less nitrogen (N) than wheat.
- Good levels of phosphorus (P), sulfur (S) and micronutrients such as zinc (Zn), copper (Cu) and manganese (Mn) are also important.
- Harvest as soon as possible. [1]

1.2 Paddock selection

Paddock selection is critical for reliable malting barley production. When selecting paddocks to grow barley, consider the following:

- Nitrogen status should be appropriate for expected yield level.
- Soil pH ($CaCl_2$) should be ≥5.0 and soil aluminium <5%.
- Avoid soils prone to waterlogging.
- In rotation, ideally sow after a root-disease break crop.
- Avoid barley on barley.
- Barley may be sown after wheat if disease or seed contamination is not a problem.
- Avoid varietal contamination.

Results from research in the southern grains region suggest that paddocks with pre-sowing soil nitrate-N levels >150 kg/ha are unsuitable for malting barley production. Paddocks with pre-sowing nitrate-N of 100–150 kg/ha were less likely to achieve barley of malting quality than those with <100 kg/ha. [2]

Informed paddock selection, suitable crop rotation and the planting of disease-resistant varieties are the best tools to minimise disease. Disease reaction for current varieties can be found at NVT South Australian Sowing Guide 2015 (p. 18) and NVT Victorian Winter Crop Summary 2015 (p. 29).

1 DAF Qld (2011) Barley malting, feed varieties and sowing times. Department of Agriculture and Fisheries Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/barley/malting,-feed-varieties-and-sowing-times

2 L Lenaghan, T Fay, M. Evans (2001) Paddock selection is critical for reliable malt barley production. Australian Agronomy Conference/the Regional Institute, http://www.regional.org.au/au/asa/2001/4/b/lenaghan.htm

1.3 Paddock rotation and history

Crop sequencing/rotation is a key part of a long-term approach to tackling weed, disease and moisture challenges in grains-region farming systems.

1.3.1 Benefits of barley as a rotation crop

Barley is a good rotation crop for breaking disease and weed cycles, and providing high stubble levels. [3] It fits well into the farming systems as a winter cereal crop.

Advantages of barley include:

- less susceptible to frost than wheat at early growth stages
- somewhat lower N fertiliser requirements than wheat
- matures faster and can be harvested earlier than wheat
- vigorous plant growth and high water-use efficiency (WUE)
- vigorous early growth—some varieties establish groundcover, which smothers weeds and produces early grazing
- produces more dry matter than wheat, leaving very good stubble cover and valuable straw for livestock feeding
- a good choice for silage or hay—can regrow to produce a good grain crop when grazed before stem elongation
- a good break crop due to differences in foliar disease responses compared with wheat

Growers should soil-test and record paddock rotations to determine adequate crop nutrition. A barley crop of 4 t/ha at 11.5% protein uses about 144 kg/ha of N and some P. [4]

1.3.2 Disadvantages of cereals as a rotation crop

Growing cereals in continuous production is no longer a common practice because of the rising incidence of:

- difficult-to-control and herbicide-resistant weeds, particularly grass weeds
- disease build-up, e.g. crown rot, *Rhizoctonia*, CCN, RLN, take-all
- N depletion and declining soil fertility

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

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

A broadleaf crop is often included in the crop sequence to counteract limitations in the cereal phase (weeds, disease, N), so the broadleaf crop's financial impact may be considerably better if considered across the crop sequence. [5]

Leading growers and advisers advocate sustainable crop sequences as a valuable strategy for southern farming systems. However, many growers are sacrificing cereal

More information

Research paper: Break crops pay in the Victorian Mallee

Research paper: Effect of agronomic management on gross margins from crop sequences in the high rainfall zone of south western Victoria

Research paper: Increasing mycorrhizal colonisation does not improve growth and nutrition of wheat on Vertosols in south-eastern Australia

Research paper: Rotation, sequence and phase. Research on crop and pasture systems

GRDC Fact Sheets: Choosing rotation crops. Short-term profits, long-term payback

GRDC Ground Cover: Crop sequencing supplement

GRDC: Integrated disease management for cereal and broadleaf crops in southern NSW and northern Victoria

GRDC Online Farm Trials: Barley and wheat disease management using foliar and fertiliser fungicides

GRDC Update Papers: Crop sequencing—what are the key issues to making profitable and sustainable decisions?

GRDC Update Papers: Drivers of profit and success—use of technology on the farm

3 DAF Qld (2012) Barley planting, nutrition and harvesting. Department of Agriculture and Fisheries Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/barley/planting-nutrition-harvesting

4 DAF Qld (2014) Barley—planting and disease guide. Department of Agriculture and Fisheries Queensland, https://www.daf.qld.gov.au/__data/assets/pdf_file/0003/145587/Barley-Planting-Guide-2014.pdf

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

yield and protein by not adopting current research findings on the use of correct sequences. [6]

1.4 Fallow weed control

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

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer before in a long fallow) is integral to cropping, particularly so as the climate moves towards summer-dominant rainfall.
- Modelling studies show that the highest return on investment in summer weed control is for lighter soils or in situations where soil water that would support continued weed growth is present. [7]

More information

GRDC Fact Sheets: Summer fallow spraying

GRDC Update Papers: Achieving good pre-emergent spray results

GRDC Update Papers: Impact of crop residues on summer fallow weeds

GRDC Update Papers: Summer weeds reduce moisture and nitrogen

GRDC: Summer fallow weed management

1.4.1 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 method can also be applied in-crop. [8]

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

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

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

More information

GRDC: Weed Webinars

GRDC: Integrated Weed Management Hub

1.5 Fallow chemical plant-back periods

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop. Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods. This is the case with sulfonylureas (SUs, e.g. chlorsulfuron).

Residual persistence and half-lives of common herbicides are shown in the Table 1. Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the SUs. On labels, this will be shown

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

7 GRDC (2012) Summer fallow—make summer weed control a priority. Western Region. Summer Fallow Management Fact Sheet GRDC, January 2012, http://www.grdc.com.au/~/media/91deacef2dd843f6bbf9fab09bfe0d65.pdf

8 C Borger, V Stewart, A Storrie. Herbicides—knockdown herbicides for fallow and pre-sowing control. Department of Agriculture and Food, Western Australia, https://www.agric.wa.gov.au/herbicides/herbicides?page=0%2C1

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. [9]

Note that there are also in-crop herbicides that have plant-back periods. Some are mentioned in Table 1. Imidazolinones are widely used in IMI-tolerant crops and are an important consideration in planning.

Table 1: Half-life of common pre-emergent herbicides and residual persistence from broadacre trials and paddock experiences [10]

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

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high-pH soils. Weed control commonly drops off within 6 weeks
Glean® (chlorsulfuron)	28–42	High. Persists longer in high-pH soils. Weed control longer than Logran®
Diuron	90 (range: 1 month–1 year, depending on rate)	High. Weed control will drop off within 6 weeks, depending on rate. Long-lasting activity observed on grass weeds such as black/stink grass (*Eragrostis* spp.) and to a lesser extent broadleaf weeds such as fleabane
Atrazine	60–100, up to 1 year if dry	High. Long-lasting (>3 months) activity observed on broadleaf weeds such as fleabane
Simazine	60 (range: 28–149)	Med./high. 1 year of residual in high-pH soils. Long-lasting (>3 months) activity observed on broadleaf weeds such as fleabane
Terbyne® (terbuthylazine)	6.5–139	High. Long-lasting (>6 months) activity observed on broadleaf weeds such as fleabane and sow thistle
Triflur® X (trifluralin)	57–126	High. 6–8 months residual. Higher rates longer. Long-lasting activity observed on grass weeds such as black/stink grass
Stomp® (pendimethalin)	40	Medium. 3–4 months of residual
Avadex® Xtra (triallate)	56–77	Medium. 3–4 months of residual
Balance® (isoxaflutole)	1.3 (metabolite: 11.5)	High. Reactivates after each rainfall event. Long-lasting (>6 months) activity observed on broadleaf weeds such as fleabane and sow thistle
Boxer Gold® (prosulfocarb)	12–49	Medium. Typically quicker to break down than trifluralin, but tends to reactivate after each rainfall event
Sakura® (pyroxasulfone)	10–35	High. Typically quicker breakdown than trifluralin and Boxer Gold®; however, weed control persists longer than Boxer Gold®
Ally® (metsulfuron-methyl)	30 (range: 14–180)	Persists longer in high-pH soils and after a dry year

More information

Agriculture Victoria: Avoiding crop damage from residual herbicides

Australian Pesticides and Veterinary Medicines Authority

NSW DPI: Using pre-emergent herbicides in conservation farming systems

NSW DPI: Weed control winter crops

1.5.1 How do herbicides break down?

Herbicides break down via either chemical or microbial degradation. Chemical degradation occurs spontaneously, the speed depending on the soil type (clay or sand, acid or alkaline), moisture and temperature. Microbial degradation depends on a population of suitable microbes living in the soil to consume the herbicide as a food source.

9 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

10 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

Both processes are enhanced by heat and moisture. However, they are both impeded by herbicides binding to the soil, and this depends on the make-up of the soil (i.e. pH, clay or sand, and other compounds such as organic matter or iron).

For these reasons, degradation of each herbicide should be considered separately and growers need to understand the soil type for each paddock and climate when interpreting re-cropping periods on the product label.

1.5.2 How can I avoid damage from residual herbicides?

Select an appropriate herbicide for the weed population present. Make sure that you consider what the re-cropping limitations may do to future rotation options. Read the entire herbicide label, including the details in fine print.

Users of chemicals are required to keep good records, including weather conditions. In the case of unexpected damage, accurate records can be invaluable, particularly spray dates, rates, batch numbers, rainfall, and soil type(s) and pH.

If chemical residues could be present, choose the least susceptible crop (refer to product labels). Optimise growing conditions to reduce the risk of compounding the problem with other stresses such as herbicide spray damage, disease and nutrient deficiency. These stresses make a crop more susceptible to herbicide residues.

Be wary of compounding a residue problem by planting a herbicide-resistant crop and spraying with more of the same herbicide group. You may avoid the problem with residues in the short term, only to be faced with herbicide-resistant weeds in the longer term. This can also have an additive effect on non-herbicide-resistant crops.

Group B. The sulfonylureas

Sulfonylureas persist longer in alkaline soils (pH >7), where they rely on microbial degradation. Residual life within the SU family varies widely, with chlorsulfuron persisting for ≥2 years and not suitable for highly alkaline soils. Triasulfuron persists for 1–2 years and metsulfuron generally for <1 year.

Legumes and oilseeds are most vulnerable to SUs, particularly lentils and medics. However, barley can also be sensitive to some SUs. Check the label.

Group B. The triazolopyrimidines (sulfonamides)

Debate remains about the ideal conditions for degradation of these herbicides. However, research in the alkaline soils of the Victorian Wimmera and Mallee, and the Eyre Peninsula in South Australia, has shown that sulfonamides are less likely to persist than SUs in alkaline soils. Plant-back periods should be increased in shallow soils.

Group B. The imidazolinones (IMIs)

Imidazolinones are very different from SUs because the main driver of persistence is soil type, not soil pH. They tend to be more of a problem on acid soils, but carryover does occur on alkaline soils. Research has shown that in sandy soils, such as on the Eyre Peninsula, they can break down very rapidly (within 15 months in alkaline soils), but in the heavy clay soils in Victoria they can persist for several years. Breakdown is by soil microbes. Non-IMI-tolerant oilseeds are most at risk. Widespread use of IMI-tolerant canola and wheat in recent years has increased the incidence of residues.

Group C. The triazines

Usage of triazines has increased to counter Group A resistance in ryegrass and because of high rates used on triazine-tolerant canola. Atrazine persists longer in soil than simazine. Both generally persist longer in high pH soils, and cereals are particularly susceptible to damage. Recent research in the USA indicates that breakdown rates tend to increase when triazines are used regularly, because the number of microbes able to degrade the herbicide can increase. This may mean that breakdown can take an unexpectedly long time in soils that have not been exposed to triazines for some years.

Group D. Trifluralin

Trifluralin tends not to leach through the soil but it can be moved into the seedbed during cultivation or ridging. Trifluralin binds strongly to stubble and organic matter and is more likely to be a problem in paddocks with stubble retention. Barley is more tolerant than wheat, oats and lentils. Use knife-points to throw soil away from seed and sow deep.

Group H. The isoxazoles

Persistence in acid soils (pH <7) has not been fully tested, but research suggests that isoxazole persistence is expected to be longer than the label recommendations for legume crops and pastures. Isoxazoles will also persist longer in clay soils and those with low organic matter. Cultivation is recommended prior to re-cropping.

Group I. The phenoxies

Clopyralid and aminopyralid can be more risky on heavy soils and in conservation cropping, where they can accumulate on stubble. Even low rates can cause crop damage up to 2 years after application. They cause twisting and cupping, particularly for crops suffering from moisture stress.

Use of 2,4-D for fallow weed control in late summer may cause a problem with autumn-sown crops. There have been recent changes to the 2,4-D label, and not all products can be used for fallow weed control; check the label. The label recommends not to sow sensitive crops, especially canola, until after a significant rainfall event. Oilseeds and legumes are very susceptible to injury from 2,4-D.

More information

Research paper: Pasture plant-back periods following application of simazine to control *Vulpia* spp.

GRDC Online Farm Trials: Residual herbicides. Group B & C carry-over

Group K. Pyroxasulfone

Pyroxasulfone relies on microbial degradation, which is favoured by in-season rainfall. Label plant-backs are important, particularly for oats, durum wheat and canola. Residues will lead to crop stunting. [11]

1.6 Genetic controls

The Clearfield® Production System is designed to deliver extended weed control and increased yield potential and crop quality. [12] It matches selected seed varieties with Intervix® (active ingredients imazamox and imazapyr), a custom-designed herbicide that can only be used on Clearfield® varieties. Refer to the herbicide label for weed species that can be controlled.

More information

BASF: Clearfield Production System

1.7 Seedbed requirements

Barley seed needs good soil contact for germination. This was traditionally achieved by producing a fine seedbed by multiple cultivations. Good seed–soil contact can now be achieved by the use of press-wheels or rollers. Soil type and soil moisture influence the choice of covering device.

Some 70–90% of seeds sown produce a plant. Inappropriate sowing depth, disease, crusting, moisture deficiency and other stresses all reduce the numbers of plants that become established. Field establishment rates can be ≤60% if seedbed conditions are unfavourable.

Seedbed preparation is also important to emergence. A cloddy seedbed can reduce emergence rates because the clods reduce seed–soil contact, stop some seedlings reaching the surface, and allow light to penetrate below the soil surface. The coleoptile

11 Agriculture Victoria (2013) Avoiding crop damage from residual herbicides. DEDJTR Victoria, http://agriculture.vic.gov.au/agriculture/farm-management/chemical-use/agricultural-chemical-use/chemical-residues/managing-chemical-residues-in-crops-and-produce/avoiding-crop-damage-from-residual-herbicides

12 Crop Care (2011) Clearfield best management practice. Crop Care Australasia Pty Ltd, http://www.cropcare.com.au/Assets/501/1/2011ClearfieldBMPWeb.pdf

senses the light and stops growing, and a leaf is produced while still below the surface. Cloddy soils also dry out more quickly. [13]

1.8 Soil moisture

1.8.1 APSIM-Barley

The APSIM-Barley module of APSIM (Agricultural Production System Simulator) simulates the growth and development of a barley crop in a daily time-step on an area basis (per m^2, not single plant). Barley growth and development in this module respond to weather (radiation, temperature), soil water and soil N. The barley module returns information on its soil water and N uptake to the soil water and N modules on a daily basis for reset of these systems. Information on crop cover is also provided to the water balance module for calculation of evaporation rates and run-off. Barley root residues are passed from barley to the surface residue and soil N modules, respectively, at harvest of the barley crop. [14]

For more information, visit: APSIM-Barley.

1.8.2 Dryland

Soil water can be effectively monitored to assist managers in crop decision support. However, highly accurate estimates of plant-available water may not be possible given the inherent variability of soils and currently available sensor technologies. [15]

Technologies to support decision-making

Several technologies will provide a level of information useful in decision support without excessive investment. Read about them at: Estimating plant available water capacity.

Devices for soil monitoring

In-situ devices that have relatively small zones of measurement and rely on good soil–sensor contact to measure soil water are at a disadvantage in shrink–swell soils where soil movement and cracking are typical. This is more important in dryland than irrigated systems because seasonal soil water levels vary from above field capacity through to wilting point or lower. Consequently, the potentially high levels of error associated with cracking and soil movement and high levels of inherent soil variability mean that increased device replication would be necessary to have confidence in results. However, this increases capital cost. Some devices (capacitance, *time-domain reflectometer*) also have an upper measurement limit over which they are unable to measure soil water accurately. This may be an issue on high clay soils where moisture content at drained upper limit is likely to be >50% volumetric, the common limit for these devices.

By comparison, the use of a portable electromagnetic induction (EMI) device to measure bulk electrical conductivity and calculate soil water has a number of advantages. EMI is quick, allowing for greater replication, measures the soil moisture of a large volume of soil (to 150 cm depth), is not affected by cracking or soil movement, and does not require installation of an access tube, thus making it available for use on multiple paddocks. On the other hand, it is unsuitable for use in saline soils and does not apportion soil water to particular layers within the soil profile. [16]

[13] N Fettell, P Bowden, T McNee, N Border (2010) Barley growth & development. PROCROP Series. Industry & Investment NSW, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/516180/Procrop-barley-growth-and-development.pdf

[14] APSIM. Crop module documentation: Barely. Agricultural Production Systems Simulator, http://www.apsim.info/Documentation/Model,CropandSoil/CropModuleDocumentation/Barley.aspx

[15] N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers, 5 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

[16] N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers, 5 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

EM38

Despite an extensive range of monitoring instruments now available, measuring paddock soil moisture remains a considerable challenge. Among the suite of instruments currently available, one that is increasingly being used by researchers and agronomists is the EM38 (Geonics Ltd, Ontario, Canada). This EMI instrument is proving to have significant application potential for determining soil properties useful in precision agriculture and environmental monitoring. It is now commonly used to provide rapid and reliable information on properties such as soil salinity and sodicity, which can then be used to identify soil management zones.

It is also used in many agronomic and environmental applications to monitor soil water within the root-zone. It provides an efficient means to monitor crop water use and plant-available water (PAW) in the soil profile throughout the growing season so that informed management decisions can be made (e.g. the application, timing and conservation of irrigation water and fertiliser). EM38 datasets have also proved valuable to test and validate water balance models, which are used to extrapolate to other seasons, management scenarios and locations.

EM38 is an easy-to-use geophysical surveying instrument that provides a rapid measure of soil electrical conductivity. Soil calibrations or qualitative assessments can be used to convert this to estimates of soil water in the root-zone. [17]

Calibration of monitoring devices

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

Calculation of the availability of soil moisture for crop use (in mm of available water) requires further processing of the data and knowledge of a soil's PAW capacity (PAWC). A suitable characteristic may be identified from the APSoil database or SoilMapp, or electronic sensor output may be used to identify the soil's water-content operating range and reasonable assumptions made on values for drained upper limit and crop lower limit. An alternative is to use Soil Water Express, a tool that uses the soil's texture, salinity and bulk density to predict PAWC and to convert electronic sensor output to meaningful soil water information (mm available water).

Modelling of soil water

Simulation of the water balance should be considered as an alternative to field-based soil-water monitoring. Considering the error surrounding in-field measurement and issues regarding installation of sensing devices, there is a reasonable argument that the modelling of the water balance, when initialised with accurate PAWC and daily climate information, is likely to be as accurate as direct measurement. APSIM and Yield Prophet successfully predict soil water and they should be considered for both fallow and cropping situations. CliMate is a suitable choice for managing fallow water. [18]

Testing for nitrate and available water by taking 0–60 cm cores prior to sowing is also common practice in the Southern Region.

Agronomist's view

[17] J Foley (2013) A 'how to' for getting soil water from your EM38 field measurements. GRDC Update Papers, 5 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-how-to-for-getting-soil-water-from-your-EM38-field-measurements

[18] N Dalgliesh, N Huth (2013) New technology for measuring and advising on soil water. GRDC Update Papers, 5 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/New-technology-for-measuring-and-advising-on-soil-water

Subsoil constraints

Soils with high levels of chloride and/or sodium or boron in their subsurface layers are often referred to as having subsoil constraints. There is growing evidence that subsoil constraints affect yields by increasing the lower limit of a crop's available soil water and thus reducing the soil's PAWC.[19]

Effect of strategic tillage

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

Tillage reduced soil moisture at most sites; however, this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received between tillage and seeding and during the growing season. The occurrence of rain between tillage and sowing or immediately after sowing is necessary to replenish soil water lost from the seed-zone. This suggests the importance of timing of tillage and of considering the seasonal forecast. Future research will determine best timing for strategic tillage in no-till. [20]

1.8.3 Irrigation

Barley has not been a traditional irrigation crop because of its susceptibility to waterlogging on older irrigation layouts and the lack of suitable varieties for the cooler and wetter environment of the southern irrigation areas. However, barley has a number of good agronomic attributes for these regions compared with other cereals.

It has a shorter growing season so it requires less water to finish and can fit into a double-cropping program. Local and export demand is normally good for malting and feed-grade barley. There are few stripe rust issues in barley (some varieties are susceptible to barley grass stripe rust); it provides good weed suppression and generally has lower input costs. These attributes, combined with the features of recently developed varieties, have led to increasing interest in barley as an irrigated crop.

Management of the crop can be flexible. Variety choice, seeding rate and fertiliser rates are determined according to how the crop will be watered, that is:

- rainfed and residual irrigation water
- restricted watering (e.g. one spring irrigation)
- fully irrigated with the aim of achieving maximum yield and targeting malting quality [21]

Barley has a high WUE rating. The plant can extract moisture from below 80 cm, and given a good starting moisture profile, high-yielding crops can be grown on limited irrigation. Yields of ≥7.3 t/ha have been recorded. Growers should target yields of 5–6 t/ha and protein content of 10.1% (dry) or 11.5% (wet basis) to maximise yield and quality. Requirements for water depend on winter rainfall and irrigation systems, but one of the crucial times to apply water for achieving malting quality is grainfill. Adequate moisture during tillering and early jointing is important for maximising potential yield. [22]

---

[19] Z Hochman *et al.* (2007) Simulating the effects of saline and sodic subsoils on wheat crops growing on Vertosols. *Australian Journal of Agricultural Research* 58, 802–810, http://www.publish.csiro.au/paper/AR06365.htm

[20] Y Dang *et al.* (2013) Tillage impact in long term no-till. GRDC Update Papers, 27 February 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till

[21] K O'Keeffe, N Fettell (2010) Barley varieties & sowing rates for irrigation. IREC Farmers' Newsletter No. 182, Autumn 2010, http://irec.org.au/farmer_f/pdf_182/Barley%20proves%20valuable%20for%20irrigation%20rotations.pdf

[22] DAF Qld (2012) Barley planting, nutrition and harvesting. Department of Agriculture and Fisheries Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/barley/planting-nutrition-harvesting

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

1.9 Yield and targets

1.9.1 Variety yield comparisons

See the National Variety Trial website to compare the performance of current barley varieties across the southern region.

1.9.2 Seasonal outlook

'*The Break*' newsletter is a good and highly regarded source of climate information for southern regions. It is produced by Agriculture Victoria regularly through season and reviews climate models and changes to key influences on southern rainfall. To view issues and to subscribe, visit: The Break, The Fast Break and The Very Fast Break Newsletters.

For tips on understanding weather and climate drivers including the Southern Oscillation Index, visit the Climate Kelpie website. Case studies of farmers across Australia recruited as 'Climate Champions' as part of the Managing Climate Variability R&D Program can be accessed at: Climate Kelpie MCV Climate Champion program.

Australian CliMate is a suite of climate analysis tools delivered on the Web, iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records to ask questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, as well as El Niño/Southern Oscillation status. It is designed for decision-makers such as farmers whose businesses rely on the weather. Download from the Apple iTunes store at: https://itunes.apple.com/au/app/australian-climate/id582572607?mt=8.

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 all years. It explores the readily available weather data and 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 and helps to answer the following questions:

- How is the crop developing compared with 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?

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 duration. Text and 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. [23]

The Bureau of Meteorology has 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. [24]

[23] Australian CliMate. Commonwealth of Australia, www.australianclimate.net.au

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

1.9.3 Fallow moisture

For a growing crop, there are two sources of water: that stored in the soil during the fallow, and that falling as rain while the crop is growing. As a grower, you have some control over the stored soil water; you can measure how much is present before you plant the crop. However, rainfall is out of your control. Long-range forecasts and tools such as the SOI can indicate the likelihood of the season being wet or dry, but they cannot guarantee rain will fall when you need it. [25]

HowWet?—a climate analysis tool

The climate analysis tool *HowWet?* (from CliMate) uses records from a nearby weather station to estimate how much PAW has accumulated in the soil and the amount of organic N that has been converted to available nitrate during a fallow. It tracks soil moisture, evaporation, run-off and drainage on a daily time-step. Accumulation of available N in the soil is calculated based on surface soil moisture, temperature and soil organic carbon.

HowWet? estimates how much rain has been stored as plant-available soil water during the most recent fallow period; it estimates how much N has been mineralised as nitrate-N in soil; and it provides a comparison with previous seasons. This information aids in the decision of what crop to plant and how much N fertiliser to apply.

Barley is grown in regions where stored soil water and nitrate at planting are important in crop-management decisions, and this tool can answer questions such as:

- How much longer should I fallow? If the soil profile is near full, perhaps the fallow can be shortened.
- Given the soil type and local rainfall to date, what is the relative soil moisture and nitrate-N accumulation over the fallow period compared with most years? (Relative changes are more reliable than absolute values.)
- Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply? [26]

Inputs:

- a selected soil type and weather station
- an estimate of soil cover and starting soil moisture

The stand-alone version of *HowOften?* uses rainfall data input by the user.

Outputs:

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

HowWet? uses a standard water-balance algorithm from *Howleaky?* and a simplified nitrate mineralisation. Further calibration is needed before accepting with confidence absolute value estimates. Soil descriptions are based on generic soil types with standard organic carbon and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation.

For more information, visit: http://www.australianclimate.net.au/About/HowWetN.

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

[26] Australian CliMate. HowWet/N. Commonwealth of Australia, http://www.australianclimate.net.au/About/HowWetN

1.9.4 Water-use efficiency

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

Water use efficiency relies on:

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

The French–Schultz approach

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

In this model, potential crop yield is estimated as:

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

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

A practical WUE equation for farmers to use developed by James Hunt of CSIRO is: WUE = (yield x 1000)/available rainfall, where available rainfall = (25% Nov.–Mar. rain) + (growing season rainfall) – 60 mm evaporation.

Agronomist's view

The French–Schultz model has been useful in providing growers with performance benchmarks; where yields fall well below these benchmarks, it may indicate something wrong with the crop's agronomy or a major limitation in the environment. There could be hidden problems in the soil such as root diseases, or soil constraints affecting yields. Alternatively, apparent underperformance could be simply due to seasonal rainfall distribution patterns, which are beyond the grower's control. [27]

Application of the French–Schultz model has been challenged in recent times. In the grainbelt of eastern Australia, rainfall shifts from winter-dominated in the south (South Australia, Victoria) to summer-dominated in the north (northern New South Wales and Queensland). The seasonality of rainfall, together with frost risk, drives the choice of cultivar and sowing date, resulting in a flowering time between October in the south and August in the north.

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

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

Researchers have analysed some of the consequences of the shift from winter to summer rainfall between southern and northern regions in terms of implications for management and breeding (see Figure 1). They note caution on the use of simple rules of thumb (French–Schultz) for benchmarking WUE, and discuss the importance of more

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

integrative and dynamic modelling approaches to explore alternatives to increase WUE at the single-crop and whole farming-system level (i.e. $/ha.mm). [28]

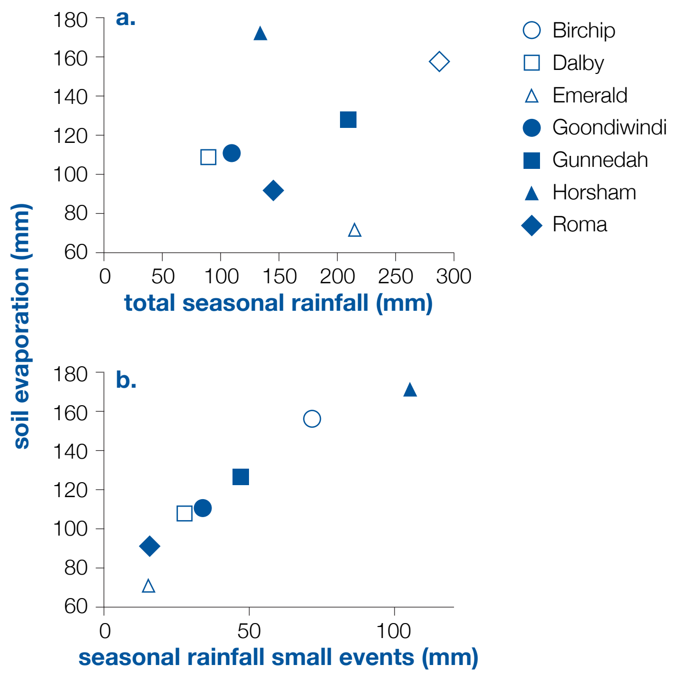

Figure 2: Simulated soil evaporation is (a) unrelated to seasonal rainfall and (b) closely related to rainfall in small events (i.e. ≤5 mm). Rainfall has three key features: amount, seasonality, and event size. The seasonality and size of events can be significant. The most widespread source of inefficiency in rainfall use, i.e. soil evaporation, is favoured by frequent and often small rainfall events. In southern locations, water supply is dominated by in-season rainfall, with characteristically small events and high evaporative losses.

More information

[GRDC: Water use efficiency of grain crops in Australia: principles, benchmarks and management]

More information

[Agriculture Victoria: How to calculate fertiliser rates and costs]

1.9.5 Nitrogen-use efficiency

Soil type, rainfall intensity and the timing of fertiliser application largely determine N losses from dryland cropping soils. Knowing the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand.

1.9.6 Other factors

A mounting body of research shows that integrated weed management (IWM) approaches incorporating strategic crop sequences and rotations, herbicides and other tactics provide effective weed control within holistic production systems.

Similarly, it has long been recognised that introduction of legumes and ley phases into cropping sequences is an important means by which long-term improvements in soil fertility can be achieved. Recent GRDC-funded research has quantified the benefits in central Queensland. [29]

1.10 Disease status of paddock

Diseases remain a major threat to barley production in Australia but are generally well controlled at present. The average annual loss from barley diseases is estimated at AU$252 million, or $66.49/ha. This compares with a potential average loss nationally

[28] D Rodriguez, V Sadras (2008) Farming systems design and water use efficiency. Challenging the French & Schultz WUE model. GRDC Update Papers, 13 June 2008, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2008/06/Farming-systems-design-and-water-use-efficiency-WUE-Challenging-the-French-Schultz-Wue-model

[29] R Sequeira (2010) Grower Solutions for Central Queensland. GRDC Research & Development, http://www.grdc.com.au/Research-and-Development/DAQ00170

of $192 million from a single disease, spot form of net blotch, which is reduced to $43 million by current controls. Major diseases in the Southern Region are CCN, spot form of net blotch, RLN, *Rhizoctonia* bare patch, take-all and crown rot. [30]

1.10.1 Soil testing for disease

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

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

- CCN (*Heterodera avenae*)
- take-all (caused by *Gaeumannomyces graminis var. tritici (Ggt*) and *G. graminis var. avenae (Gga))*
- Rhizoctonia bare patch (caused by *Rhizoctonia solani* AG8)
- RLN (*Pratylenchus neglectus* and *P. thornei*)
- crown rot (caused by *Fusarium pseudograminearum*)
- stem nematode (*Ditylenchus dipsaci*)

Grain producers can access PreDicta B from Primary Industries and Regions SA/South Australian Research and Development Institute. 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. This is best achieved by sending samples of affected plants to your local plant pathology laboratory.

For more information, visit: http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b.

1.10.2 Cropping history effects

Continuous cereal cropping increases the risk of diseases, including crown rot. This fungal disease is hosted by all winter cereals and many grassy weeds and the fungus can survive for many years in infected plant residues. Infection can occur when plants come in close contact with those residues. High cereal intensity and inclusion of durum wheat in cropping programs are factors that increase crown rot levels. [31]

1.11 Nematode status of paddock—testing of soil

Paddocks should be tested for plant parasitic nematodes so that optimal management strategies can be implemented. Testing your farm will tell you:

- whether nematodes are present and at what density
- which species are present

It is important to know which species are present because crops and varieties have different levels of tolerance and resistance to different species of nematodes.

If a particular species is present in high numbers, immediate decisions need to be made to avoid losses in the next crop to be grown. When low numbers are present, it is important to take decisions to safeguard future crops. Learning that a paddock is free of these nematodes is valuable information because it may be possible to take steps to avoid future contamination of that field. [32]

[30] GM Murray, JP Brennan (2009) The current and potential costs from diseases of barley in Australia. GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Disease_Loss_Barley_Report_240809.pdf

[31] GRDC (21014) Managing crown rot. Hot-Topics. Media Centre, GRDC, http://www.grdc.com.au/Media-Centre/Hot-Topics/Managing-crown-rot

[32] DAF Qld (2009) Root lesion nematodes—management of root-lesion nematodes in the northern grain region. Department of Agriculture and Fisheries Queensland, https://www.daf.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

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

For more information, visit: http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b.

1.12 Insect status of paddock

1.12.1 Insect sampling of soil

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

Soil insects include:

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

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

- Weedy fallows and volunteer crops encourage soil insect build-up.
- Insect numbers decline during a clean long fallow due to lack of food.
- High levels of stubble on the soil surface can promote some soil insects (i.e. a food source); however, pests may continue feeding on the stubble instead of on 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 decline if stubble levels are very low.

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

Soil sampling by spade

1. Take a number of spade samples from random locations across the field.
2. Check that all spade samples are deep enough to take in the moist soil layer (this is essential).
3. Hand-sort samples to determine type and number of soil insects.
4. Spade sampling is laborious, time-consuming and difficult in heavy clay or wet soils.

Germinating seed bait technique

Immediately following planting rain:

1. Soak insecticide-free crop seed in water for at least 2 hours to initiate germination.
2. Bury a dessertspoon of the seed under 1 cm of soil at each corner of a 5 by 5 m square at five widely spaced sites per 100 ha.
3. Mark the position of the seed baits because high populations of soil insects can destroy the baits.

4. One day after seedling emergence, dig up the plants and count the insects.

Trials have shown that there is no difference in the type of seed used when it comes to 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.

Recognising soil insects

For more information, see *GrowNotes Barley South Section 7. Insect control* .

Detecting soil-dwelling insects

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

For current chemical control options see Pest Genie or APVMA. [33]

1.13 Snails

More information

GRDC Hot Topics: Snail control before seeding

GRDC Fact Sheets: Snail bait application

VNTFA: Slugs

With the increased prevalence of snails and slugs in the southern cropping region in recent years, the GRDC has invested in a number of research and development programs mapping different species and looking at a range of control measures.

Have you noticed snails in grain at harvest? Are snails easily seen in some paddocks? If you answered yes to either of these questions, consider control measures in the lead up to sowing rather than after crops have germinated.

Use a 32 cm by 32 cm square quadrat and count all of the live snails in it. Multiplying by 10 will give an estimate of snails per m^2. Live snails are those that are moist when squashed. Taking many sampling points within paddocks known to have snails will give a good indication of their numbers and of where they are mostly found. [34]

1.14 Mouse management

More information

GRDC Ground Cover: Mouse management a numbers game

GRDC Update Papers: Surveillance and forecasts for mouse outbreaks in Australian cropping systems

GRDC Fact Sheets: Mouse control—Western Region

During years of high mouse activity, young winter crops can be severely damaged. Growers need to monitor crops closely and determine whether zinc phosphide baiting should be carried out to reduce damage to summer crops and protect newly sown winter crops. Growers are reminded that there is a 2-week withholding period for zinc phosphide baits prior to harvest. Talk to your neighbours and coordinate a baiting program to reduce reinvasion. [35]

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

34 GRDC (2014) snail control before seeding. Hot Topics. Media Centre, GRDC, http://grdc.com.au/Media-Centre/Hot-Topics/Snail-control-before-seeding

35 J Farrell, PR Brown (2014) Mouse plague prediction models: relevant forecasts for growers in Queensland. GRDC Update Papers, 5 March 2014, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Mouse-plague-prediction-models-relevant-forecasts-for-growers-in-Queensland