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GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

TRITICALE

SECTION 1

PLANNING / PADDOCK PREPARATION

PADDOCK SELECTION | PADDOCK ROTATION AND HISTORY | FALLOW WEED CONTROL | FALLOW CHEMICAL PLANT-BACK EFFECTS | SEEDBED REQUIREMENTS | SOIL MOISTURE | YIELD AND TARGETS | DISEASE STATUS OF PADDOCK | NEMATODE STATUS OF PADDOCK | INSECT STATUS OF PADDOCK

Planning/Paddock preparation

Key messages

- Triticale is suited to all soil types but has a significant yield advantage over wheat and barley when grown in a number of problem soil situations.
- Of all the cereals available to farmers, triticale has the best adaptation to waterlogged soils and those of high pH (alkaline soils).
- Triticale is also tolerant of low pH (acid soils), grows well on sodic soils and tolerates soils high in boron.
- Triticale can out-produce other winter cereals on lighter, lower fertility soils. It has more vigorous root system than wheat, barley or oats binding light soils and extracting more nutrients from the soil.
- Incorporate crop rotation in farming systems – triticale can provide valuable benefits to a sequence.
- Ensure that paddocks are weed free before planting seed.
- Test soils for disease and nematodes and sample paddock soil for insects.

1.1 Paddock selection

Choice of paddock to sow cereals is based on a range of issues. Economics, production risk from disease or weed pressures, herbicide residues, seasonal forecasts, stored soil water, and achieving a balance of risk with other crop types are some of the considerations. [1]

1.1.1 Topography

Topographical characteristics can determine crop and pasture options. Crops and varieties prone to lodging should be avoided in uneven paddocks. Waterlogged conditions also reduce root growth and can predispose the plant to root rots. Triticale is less prone to waterlogging than other cereals so can be a good option for areas where water may sit. The topographic variations typical of large agricultural paddocks can have a substantial impact on dynamics of soil mineral nitrogen (N) as well as on performance of crops. spatial variations in soil organic matter, soil microbial biomass, natural drainage, plant growth, and water and nutrient redistribution caused by topography are the main factors controlling the dynamics of soil mineral N. Along with weather, landscape topographic patterns accounted for most of the variations in plant available N.

There are potential environmental and economic benefits of site-specific topography-driven cover crop management. Management decisions regarding where to plant crops can vary depending on the management goals and complexity of the terrain. For example, cover crops seem to be particularly advantageous on eroded unfertile slopes where legumes bring the needed N inputs, and all cover crops contribute to erosion control and Carbon sequestration. [2]

1.1.2 Soil

Soil characteristics (surface and subsurface) such as soil pH, sodicity, salinity, acidity, texture, drainage characteristics and compaction will affect variety selection.

1 Agriculture Victoria (2012) Growing wheat. DEDJTR Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-wheat

2 Ladoni, M., Kravchenko, A. N., & Robertson, G. P. (2015). Topography Mediates the Influence of Cover Crops on Soil Nitrate Levels in Row Crop Agricultural Systems. *PloS one*, *10*(11), e0143358.

Of all the cereals available to farmers, triticale has the best adaptation to waterlogged soils and those of high pH (alkaline soils). Triticale is also tolerant of low pH (acid soils), grows well on sodic soils and tolerates soils high in boron. In nutrient deficient soils, triticale appears to respond better to applied fertilisers than other cereals. Triticale has the capacity to survive utilising trace elements in soils which would be considered nutrient deficient for any other type of crop. [3]

Triticale is suited to all soil types but has a significant yield advantage over wheat and barley when grown in a number of problem soil situations including:

- Acidic soils (pH less than 4.5 $CaCl_2$) which are high in aluminium (greater than 10% of the total cations) e.g. WA, southern NSW and north east Vic.
- Alkaline soils
- Waterlogged conditions. [4]

NVT experiments on alkaline soil in southern Australia, have indicated good yields compared with other cereals, even in dry years. Farmer experience on dry rocky soils in southern Australia has shown a 25% yield advantage for triticale, compared with wheat. In these difficult conditions, the variety Rufus has proved most valuable. [5]

Triticale will grow on similar soils to wheat and barley, but is also adapted to soils that are too acid for the other cereals. It is relatively boron tolerant and is tolerant to high aluminium soils. On alkaline soils where other cereals are affected by manganese, zinc or copper deficiency triticale is less affected.

Triticale can out-produce other winter cereals on lighter, lower fertility soils. It has more vigorous root system than wheat, barley or oats binding light soils and extracting more nutrients from the soil. [6]

Triticale and wheat are similar crops, but triticale represents a valuable alternative to wheat due to its greater biomass production and grain yield in Mediterranean-type growing conditions, such as those in parts of western Australia. [7]

IN FOCUS

The impact of different soil moisture and soil compaction on the growth of triticale root system

Effects of different soil moisture (soil drought and waterlogging) and soil compaction (1.33 and 1.50 g·cm−3) on the growth and morphological traits of the root system were studied in four breeding forms and seven cultivars of triticale. Morphological changes, including the restriction of root extension, expansion and proliferation of laterals roots, occur in plants grown in different soil moisture and in compact soil. Results have demonstrated a relatively broad variation in the habit of the triticale root system. Plants grown under compact soil and low or high soil water content showed a smaller number and less dry matter of lateral branching than plants grown in control conditions. The harmful effects of compact soil and drought conditions on the growth of roots was greater when compared with that of plants exposed to waterlogging. The observed effects of all treatments were more distinct in a drought sensitive strains. The drought resistant forms were more characterized with extensive rooting and by smaller alterations in the root morphology under the stress conditions compared with drought sensitive one (Photo 1). Results confirm that the

3 Agriculture Victoria. (2012). Growing Triticale. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale

4 Waratah see Co. Ltd. (2010). Triticale: planting guide. http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

5 Jessop RS, Fittler M. (2009). Triticale production Manual – an aid to improved triticale production and utilisation. http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

6 Birchip Cropping Group. (2004). Triticale agronomy – 2004. http://www.farmtrials.com.au/trial/13801

7 Bassu, S., Asseng, S., Giunta, F., & Motzo, R. (2013). Optimizing triticale sowing densities across the Mediterranean Basin. *Field Crops Research*, *144*, 167–178.

breeding forms (CHD-12 and CHD-173) of a high drought susceptibility was found to be also more sensitive to periodical soil water excess. A more efficient water use and a lower shoot to root (S/R) ratio were found to be major reasons for a higher stress resistance of the breeding forms (CHD-220 and CHD-247). The reasons for a different response of the examined breeding forms and cultivars to the conditions of drought or waterlogging may be a more economical water balance and more favourable relations between the shoot and root dimensions in the drought resistant forms and cultivars. [8]

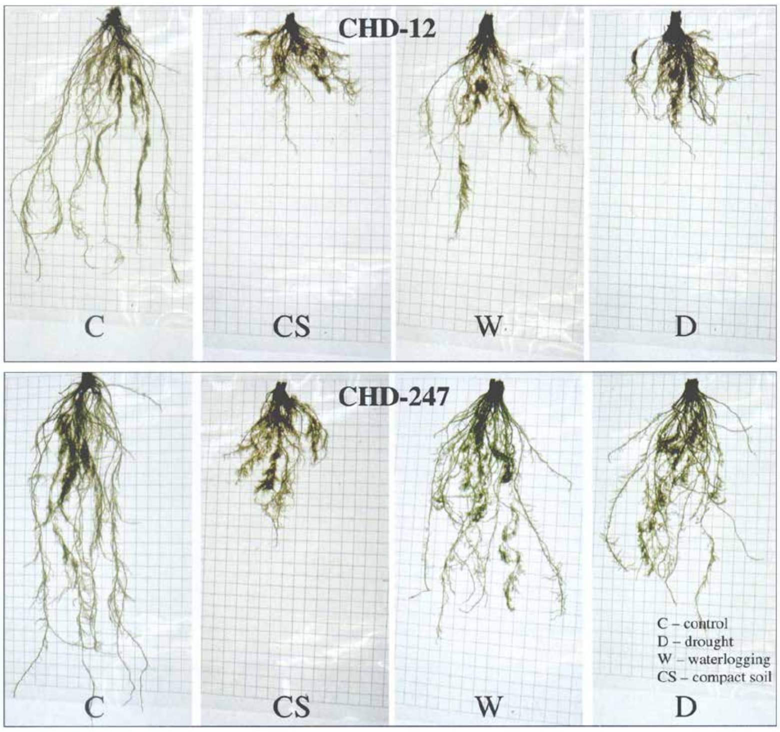


Photo 1: *Effects of compact soil (CS), waterlogging (W) and soil drought (D) on root growth of drought resistant (CHD-247) and drought sensitive (CHD-12) 3-weeks old triticale seedlings.*

Soil compaction has been found to limit triticale growth. Severe soil compaction treatments decreased leaf number, leaf area and dry matter of shoots and roots, while increasing shoot-to-root dry matter ratio. In addition, high level of soil compaction strongly affected the length of seminal and seminal adventitious roots, and the number and length of lateral roots developed on the seminal root. Severely compacted soil also negatively impacts photosynthesis, gas exchange, transpiration rate and stomatal conductance. [9]

Soil pH

Key points:

- Triticale can grow on acidic soils (pH less than 4.5 $CaCl_2$) and alkaline soils
- Soil pH is a measure of the concentration of hydrogen ions in the soil solution.

8 Grzesiak, S., Grzesiak, M. T., Filek, W., Hura, T., & Stabryła, J. (2002). The impact of different soil moisture and soil compaction on the growth of triticale root system. *Acta Physiologiae Plantarum*, *24*(3), 331–342.

9 Grzesiak, M. T. (2009). Impact of soil compaction on root architecture, leaf water status, gas exchange and growth of maize and triticale seedlings. *Plant Root*, *3*, 10–16.

- 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.
- Soil acidity is a major constraint to farming in Western Australia.

As a general rule, Triticale's are suited to all soil types, but typically have a yield advantage over wheat and Barley on light acidic soils higher in exchangeable Aluminium. In these acidic soils higher in Aluminium, Canobolas⊕ and Bogong⊕ would be the two most preferred varieties of choice. [10]

In 2011, a trial tested triticale growth in soils with low subsoil pH and aluminium toxicity on a property east of Perenjori, WA. After being attacked by cutworm 4 weeks after sowing the triticale regenerated quickly. The newer varieties, Berkshire⊕ and Speedee, yielded higher than the Tahara (Table 1). [11]

Table 1: *Yield and quality of triticale varieties grown on low subsoil pH and aluminium toxicity soils in WA.*

Variety	Yield (t/ha)	Protein (%)
Berkshire⊕	1.14	11.5
Speedee	0.94	11.8
Tahara	0.77	11.8

Source: Liebe Group, 2011

Another earlier trial in WA investigated the benefits of soil amendments on acid soil for triticale and wheat. There was a significant yield improvement of Tahara triticale when gypsum was applied to the surface to treat subsurface acidity. Wheat did not show the same response. Whilst the variety Wyalkatchem does have good tolerance to aluminium, triticale is highly tolerant, and would be expected to be the least likely to respond to changes in levels of toxic aluminium in the subsoil. The liming sources of lime sand and dolomite had no effect on yield of either the triticale or wheat in the first year of application. Due to their solubility the effects of these liming sources may be seen in the next few years. [12]

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 1).

10 Viterra. Bongong and Canobolas⊕ Triticale – SA/Vic/NSW seed factsheet. http://www.hartbrosseeds.com.au/f.ashx/Bogong⊕-Canobolas⊕-Factsheet.pdf

11 Johnston C. (2011). Triticale variety demonstration. Liebe Group. http://www.farmtrials.com.au/trial/10587

12 Conley T, Mureschi L. (2003). Soil amendments. Liebe Group and CSBP. http://www.farmtrials.com.au/trial/10324

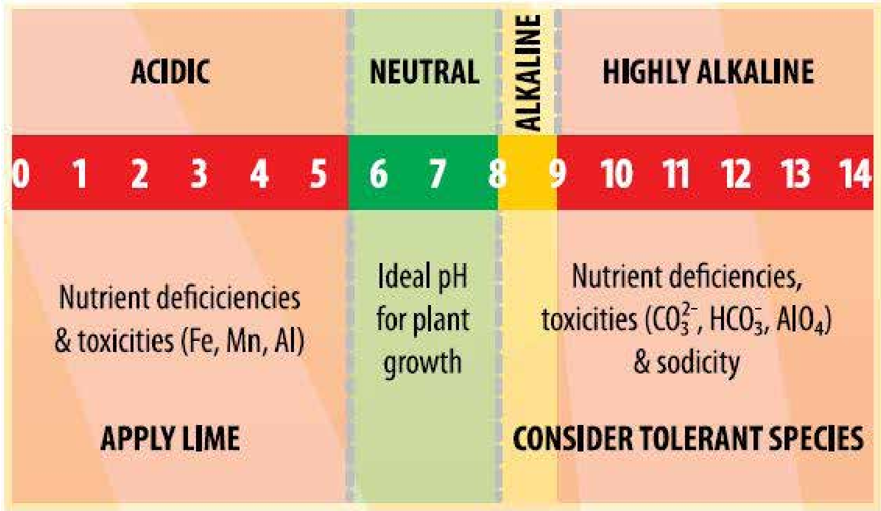


Figure 1: *Classification of soils on the basis of pH (1:5 soil:water), the implications for plant growth and some management options.*

Source: Soilquality.org. 13

Subsurface acidity is a major constraint to crop and pasture productivity right across WA's grain belt, estimated to reduce crop yields by 9–12%.

More than 70% of surface soils and almost half of subsurface soils across WA's south-west are below appropriate pH levels for agricultural production (Figure 2).

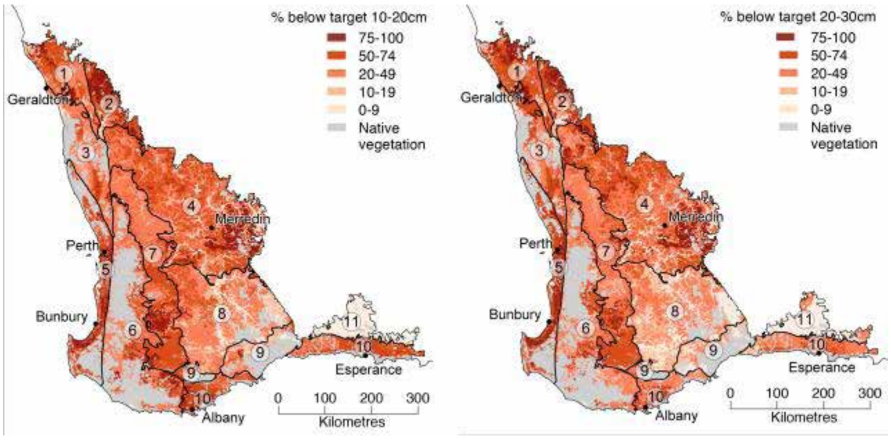


Figure 2: *Percentage of sites sampled (2005–12) with soil pH at 10–20 cm depth (left) and 20–30 cm (right) below the DAFWA target of pHCa 4.8.*

Source: Gazey et al. 2013 in DAFWA

Some trace elements become more soluble at lower pH, as does aluminium (Al), which is toxic to plants when in solution. If soil pH is too low – below about 4.8 – the concentration of Al in the soil water increases rapidly and reduces root growth. The resultant smaller root systems have limited access to nutrients and water, leading to lower plant biomass and grain yields.

Adding lime to the soil raises the pH. Above pH 4.8 the Al becomes non-toxic in the soil, enabling the plants to develop effective root systems. Research shows that as well as improving crop yields and widening rotation options, liming has a long-term positive impact on the ecosystem by potentially boosting soil microbial activity, improving availability of major plant nutrients and helping to reduce weed seed banks.

13 Soilquality.org. Soil pH- South Australia. http://www.soilquality.org.au/factsheets/soil-ph-south-australia

MORE INFORMATION

Soil acidity in Western Australia

VIDEOS

WATCH: GCTV8: Liming Acids Soils.

PODCAST

LISTEN: Ground Cover Radio 109 Crop roots push deeper after lime.

DAFWA's recommended minimum pH levels for WA's agricultural soils to maintain or achieve yield potential (measured in pH calcium chloride– or pHCa) are:

- Surface (0–10 cm) pHCa 5.5
- Subsurface (10–20 cm and 20–30 cm) pHCa 4.8, and no less than pHCa 4.5 to avoid Al toxicity.

Yields should not be constrained by acidity when these levels are met.

Lime use is most effective if it is precisely targeted to property areas based on subsurface soil testing during the summer months to a depth of at least 30 cm (in 10 cm increments), and to 40 or 50 cm on sandy soil. Scheduled liming applications are required to maintain the desired pH level in the soil, with priority given to the farm's most productive cropping areas.

It is important that growers source the best value for money lime based on neutralising value (i.e. the carbonate content of lime determines the capacity of the lime to neutralise acidity) and particle size (i.e. the size of the lime particles determines how quickly the lime can neutralise acid). Lime with a high proportion of finer particles has a larger surface area to react with the acid in the soil.

Mechanically incorporating lime into the subsurface during amelioration with deep tillage, spading or mouldboard ploughing generally achieves more rapid improvements in subsurface pH levels. Variable rate technology can also be successfully applied to lime spreading. [14]

Measurement of soil pH

Soil sampling and measurement of pH helps to determine the practices necessary to manage land with low or high pH. Sampling strategies need to take into account the variation across a paddock and down the soil profile (see section below).

Soil pH can be measured by a simple device called an ion electrode inserted into a mixture of one part soil to five parts water. Scientists dealing with acid soils with pH less than 5 prefer to measure soil pH using soil in calcium chloride solution. This is not suitable for soils with a pH greater than 5 because some of the ions in these soils (mainly bicarbonate and carbonate) become bound to the calcium and are removed from solution, which then causes an inaccurate pH reading. Soils with pH greater than 5 should be measured in water. [15]

1.1.3 Sampling soil quality

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

14 GRDC. (2016). Soil acidity in WA. GRDC Hot Topics. https://www.agric.wa.gov.au/soil-acidity/soil-acidity-western-australia

15 Soilquality.org. Soil pH – South Australia. http://www.soilquality.org.au/factsheets/soil-ph-south-austral

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.

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

Sampling strategy

Soil properties and fertility often vary considerably, even over short distances, necessitating a sampling strategy which either integrates this variation through creating a composite sample (sampling across) or describes it through including replicate samples (sampling within). Describing the variation requires a defined sampling within each different soil patch and analysing replicate samples separately. Such an approach might be required where there are consistent zones within a field such as under controlled traffic systems, perennial row or tree crops or raised bed systems. More often, the variation within the field is integrated into a single sample through creating a composite. Examples of these are illustrated in Figure 3. 'A' is a random sampling that integrates the variation across the field, but samples are strategically located such that the location of samples approximates the relative representation of the different soil types. Sampling type 'B' uses a transect method to integrate the variation across the field, and in 'C' equal numbers of samples are taken from each zone and the area samples kept separate to obtain different soil analyses for each zone.

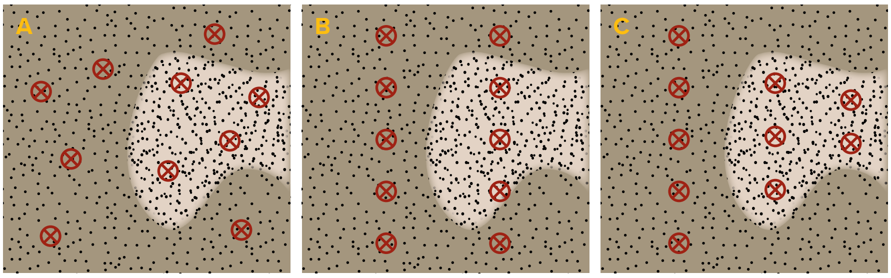


Figure 3: *Sampling strategies used to create a composite sample that integrates variation across different soil types (A & B) and a strategy to describe variation by sampling zones and analysing samples separately ©. A: haphazard samples strategically located to approximate the relative representation of different soil types. B: samples taken along transects intersecting different soil types. C: equal numbers of samples from each zone.*

Source: Soilquality.org

Sampling equipment

Manual sampling is often used where sampling is only required to 10 cm and bulk density is not required. Small pogo type samplers enable quick sampling for qualitative determinations such as nutrient concentrations or disease presence. Ensure that your sampling equipment is cleaned before you start to avoid contamination. For deeper depths mechanical (hydraulic) samplers are usually required for most soil types. If using these for soil carbon sampling be careful not to contaminate samples with lubricating oil.

Sampling depth

Sampling for soil fertility or biological activity assessment is typically done to 10 cm depth as this is where most of the organic matter and nutrient cycling occurs. However, 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. 10, 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.

Sample handling

Samples can be stored in polythene bags but should generally be dried or kept cool prior to analysis. Air drying (< 40°C) is usually sufficient and storage below 4°C usually arrests most biological activity. Dried samples can be broken up if clods are present, and any stones removed. If the amount of material collected is too great to manage and ship then it can be reduced in size by careful quartering, ensuring that there is no discrimination against particular particle sizes. Samples are typically put through a 2 mm sieve prior to analysis. [16]

1.1.4 Paddock selection for forage cereals

Selecting a paddock for forage cereal production will depend on how the forage cereal will be used on the dairy farm. If the forage cereal is to provide additional grazing, then a well drained paddock that can resist pugging damage from dairy cows should be chosen. A paddock that has higher fertility and is well drained should be chosen to provide maximum dry matter production.

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

It is best to select a paddock that has a low level of pasture grasses to avoid the risk of cereal disease transmission. Annual pasture grasses can be hosts for such diseases as Take-all, Rhizoctonia, Fusarium and Pythium. In traditional cereal growing areas, pasture grasses can be removed from the paddock in the year prior to cereal establishment by using herbicides to 'winter clean' the pasture or by green manuring to prepare the seed-bed.

Tough grasses such as bent grass, couches and kikuyu must be satisfactorily controlled before autumn sowing of cereals. These grasses will compete with the cereal for nutrients and moisture, both in autumn at establishment and in the following spring. [17]

1.1.5 Weed burden and herbicide history

A high weed burden will influence the likelihood of cropping success. The species present or likely to occur based on previous years should influence crop species choice to ensure that effective in-crop control measures are available.

Strategic and integrated weed management over a rotation can greatly increase the likelihood of controlling weeds across all crops. Paddocks being planted to cereals in the first year of rotation should for instance have a vigilant strategy for the control and prevention of seed set of key broadleaf weeds prior to a rotation to canola or legume crops.

The use of pre-emergent herbicides as appropriate should be considered as well as cultural control methods such as species choice and row width.

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonylurea, triazines, etc.) may be an issue in some paddocks. Remember that plant-back periods begin after significant rainfall occurs.

For more information, see Section 6: Weed Control.

1.1.6 Fallow moisture and management

Paddocks with well-managed fallow periods significantly lower the risk of poor crop and financial performance. A growing crop has two sources of water: the water stored in the soil during the fallow, and the water that falls as rain while the crop is growing. Growers have some control over the stored soil water; measure soil water 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 needed. Timely weed control can reduce moisture and nutrition loss, prevent an increase in the seedbank, and decrease the risk of disease carryover. Absence (or restriction) of grazing periods maintains soil friability and groundcover. Prolonged grazing periods may create crop emergence problems through induced surface compaction. [18]

1.2 Paddock rotation and history

Paddock choice can determine the amount of disease, weed and nutrient pressure on the crop. Increasing interest in crop sequencing is providing more financial and agronomic data to help growers to choose crops and paddocks each year. 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. Leading growers and advisers advocate sustainable crop sequences as a valuable strategy for southern farming systems. Many growers are sacrificing cereal yield and protein by not adopting current research findings on the use of correct sequences. 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,

17 Agriculture Victoria. (2008). Establishing forage cereals.

18 N Border, K Hertel, P Barker (2007) Paddock selection after drought. NSW Department of Primary Industries, February 2007.

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. [19]

1.2.1 Triticale as rotation crop

Besides its use as a feed grain, triticale can be used as a forage crop for ruminants and as a cover crop.

When added to a rotation, triticale may increase yields of other crops in the rotation, reduce costs, improve distribution of labour and equipment use, provide better cash flow, and reduce weather risk. Additionally, production of triticale may provide environmental benefits, such as erosion control and improved nutrient cycling. [20]

Triticale yields more than its ancestors in two types of marginal conditions; highlands where acid soils, phosphorus deficiency and foliar diseases are dominant, and in the arid and semi-arid zones where drought affects crops production. [21]

Observed traits suggested for the higher yields in triticale than wheat include greater early vigour, a longer spike formation phase with same duration to flowering, reduced tillering, increased remobilisation of carbohydrates to the grain, early vigorous root growth and higher transpiration use efficiency. [22]

Trials in the UK suggest that triticale gives a greater yield advantage than wheat in the second cereal position in a rotation. The main reason for this difference was thought to be triticale's better resistance to take-all. [23]

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

20 Gibson LR, Nance C, Karlen DL. (2005) Nitrogen management of winter triticale. Iowa University. http://farms.ag.iastate.edu/sites/default/files/NitrogenManagement.pdf

21 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org..

22 Bassu, S., Asseng, S., & Richards, R. (2011). Yield benefits of triticale traits for wheat under current and future climates. *Field Crops Research*, *124*(1), 14–24.

23 Clarke S, Roques S, Weightman R, Kindred D. (2016). Understanding Triticale. https://cereals.ahdb.org.uk/media/897536/pr556-understanding-triticale.pdf

Table 2: *Advantages and disadvantages of including triticale in crop rotations.*

Advantages	Disadvantages
Triticale is a relatively low input cereal crop with good disease resistance, particularly to rusts. It is as high a quality feed grain as wheat and is a hardy plant. It is a tall crop bred for strong straw strength which can be useful in rocky paddocks or circumstances where crops have been known to lodge. Triticale is more durable than wheat when grazed; which means it will be healthier and stand up to weeds, diseases and cold weather better than wheat. Many growers use triticale as a disease break in their rotations and value the benefits of triticale for its contribution to soil conservation. Thus, triticale assists in maintaining soil health by the reduction of nematodes, such as *Pratylenchus neglectus* and *thornei* (root lesion nematodes) and *Heterodera avenae* (cereal cyst nematode), and a range of fungi and bacteria that build up in the soil, reducing yields when the same crop species is grown repeatedly. Other favoured characteristics of triticale are its resistances to barley yellow dwarf virus, mildew and rusts, which may cause significant yield reductions in wheat, barley and oats. The extensive root system of triticale binds sandy soils, and the fibrous stubble reduces wind and water erosion. [24] Roots of triticale in nematode infested soil have been found to contain fewer nematodes than other cereals. Triticale is thus a useful rotational crop for areas infested with the root lesion nematode. [25]	One of the drawbacks of triticale grown for grain is that it is prone shattering. There is a spot about a quarter to a third of the way down from the tip on the rachis that is very weak. [26] Stripe rust may be a problem in triticale and there are now options to treat seed to provide seedling protection against stripe rust. Triticale grain is softer than wheat and barley grain. Soft grain is more prone to attack from weevils and other grain storage insects. [27] It can be difficult to find a market for triticale.

Benefits of cereals as a rotation crop

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

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, tan (yellow) spot, nematodes
- nitrogen (N) depletion and declining soil fertility

1.2.2 Break cropping

Farmers use their soil intensively. There are pressures to grow more and more crop - in volume or value - to maintain profits. Despite this, it is still important to grow cover crops. Cover or "break" crops include grasses such as triticale, rye and oats, and legumes such as cowpeas and vetch. They may be ploughed in and are called

24 Cooper KV, Jessop RS, Darvey NL in Mergoum, M., & Macpherson, H. G. (2004). Triticale improvement and production (No. 179). Food & Agriculture Org. http://www.fao.org/docrep/009/y5553e/y5553e00.htm

25 Vanstone, V., Farsi, M., Rathjen, T., & Cooper, K. (1996). Resistance of triticale to root lesion nematode in South Australia. In Triticale: Today and Tomorrow (pp. 557-560). Springer Netherlands.

26 Alternative crops – Triticale in the US.

27 Agriculture Victoria. (2012). Growing Triticale. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale

"green manure" crops. These crops may also be mulched, slashed or sprayed, then later turned into the soil (incorporated).

For more information, see Section 2: Pre-planting.

Although cover crops do not normally produce income, they are important because they protect the soil and give other benefits (Table 3). Bare soil is easily damaged, it is best to protect it by maintaining plant cover. [28]

Much of the practice being adopted on farm in Australia involves the use of crops that can provide green manure benefits, but in most cases they host and multiply nematodes, and there is little information about their impacts on other soil borne fungi. [29]

Table 3: *Advantages and disadvantages of including cover crops in growing rotations.*

Advantages of cover cropping	Disadvantages of cover cropping
Protect the soil: much less erosion - soil washing away - and less surface crusting. Maintain fertility: by maintaining organic matter levels in the soil and, if a legume, adding nitrogen. Weed control: a healthy cover crop keeps a paddock free of weeds. Disease control: can provide a "break crop" that helps reduce disease, nematode, and perhaps pest, levels. For vegetable production, grasses rather than legumes tend to be best for this benefit. Biological tillage: less cultivation is needed because cover crops loosen the soil. Improved paddock access: cover crops can dry out a soil underneath and help farm operations to be timely. This drying out also makes nitrogen in the soil more available.	**Loss of land for cash crops**. If it is necessary to avoid this, do not grow the cover crops to maturity and grow only occasionally. A cover crop only once every two years still provides worthwhile benefits. On the other hand, once a year is better. **Cost of seed and sowing:** these costs are unavoidable but small. The costs associated with growing, such as watering, are usually avoidable. **Can become a weed**: usually not a problem in vegetable production. **Bulky crops**: can temporarily tie-up nitrogen and perhaps increase disease and have other effects. Their trash can also get in the way. If nitrogen deficiency in the following crop may be a problem, incorporate the cover crop earlier - for example 4–6 weeks before planting - or apply a nitrogen fertiliser to speed-up breakdown of the cover crop

Source: DPI NSW

VIDEOS

WATCH: The importance of Crop rotation.

1.2.3 Long fallow disorder

Soils naturally contain beneficial fungi that help the crop to access nutrients such as phosphorus (P) and zinc (Zn). The combination of the fungus and crop root is known as arbuscular mycorrhiza(e) (AM). Many different species of fungi can have this association with the roots of crops. Many that are associated with crops also form structures called vesicles in the roots. The severe reduction or lack of AM shows up as long fallow disorder—the failure of crops to thrive despite adequate moisture. Ongoing drought in the 1990s and beyond has highlighted long fallow disorder where AM have died out through lack of host plant roots during long fallow periods. As cropping programs restart after dry years, an unexpected yield drop is likely due to reduce AM levels, making it difficult for the crop to access nutrients. Long fallow disorder is usually typified by poor crop growth (Photo 3). Plants seem to remain in their seedling stages for weeks and development is very slow.

28 Senn A. 2007. Protect your land – use cover crops. DPI NSW. http://archive.dpi.nsw.gov.au/content/agriculture/horticulture/protect

29 Cover cropping practices multiplying nematodes. 2014. http://www.goodfruitandvegetables.com.au/story/3554224/cover-crop-practices-multiplying-nematodes/

Photo 3: *A crop affected by long fallow disorder.*

Source: DAFF

Benefits of good AM levels are:

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

In general, the benefits of AM are greater at lower soil P levels because AM increase a plant's ability to access this nutrient. Crops with higher dependency benefit more from AM (Table 4). [30]

Table 4: *The dependency of various crop species on mycorrhiza (value decreases as the phosphorus level of the soil increases)*

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

Source: DAFF

1.3 Fallow weed control

Paddocks with well-managed fallow periods significantly lower the risk of poor crop and financial performance. The best form of weed control is rotation and careful selection of paddocks largely free from winter weeds (Photo 4).

When sowing dual purpose varieties early, choose a paddock with low weed numbers and control weeds prior to the first grazing. Strategic grazing can be used to help manage weeds. Always check grazing withholding periods before you apply post-emergent herbicides when planning to graze the crop. [31]

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

31 Waratah see Co. Ltd. (2010). Triticale: planting guide. http://www.porkcrc.com.au/1A-102_Triticale_Guide_Final_Fact_Sheets.pdf

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

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer before in a long fallow) is integral to winter cropping, 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. [32]

1.3.1 Controlling summer weeds

Effective weed control can reduce weed numbers in subsequent years and run down the seedbank. Uncontrolled weeds contribute massively to the soil seed bank, creating increased costs of control and future weed burdens. This may limit crop choice and reduce flexibility in systems.

Summer weed control can be expensive but is necessary to prevent problems with excessive growth and/or moisture and nitrogen loss from the soil. When using herbicides:

- Water rates should be kept high (at least 60 litres per hectare).
- Add a surfactant and/or spraying oil to all post-emergent treatments unless otherwise directed on the label.
- Do not spray stressed plants.
- Spray grazing can be effective at high stocking rates.
- Glyphosate, 2,4-D, metsulfuron, atrazine and triclopyr are the most common herbicides used for summer weed control.
- Where summer grasses are present, glyphosate at rates around 2 L/ha are generally required.

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

- Metsulfuron provides cheap control of wireweed, triclopyr is generally preferred for melon control and atrazine for small crumbweed (also known as mintweed or goosefoot).
- 2,4-D controls a wide range of broadleaved weeds and is preferred if stock are available for spray grazing. The ester formulations are usually more effective for summer weed control because they are oil soluble and more able to penetrate the waxy surfaces or stubble.
- Moisture stress in weeds is common in summer and reduces the effectiveness on most herbicides. This can be partially overcome by spraying early in the morning. However at this time of day, inversions may be present which could lead to excessive drift. Avoid spraying during still conditions. [33]

1.3.2 The green bridge

The green bridge provides a between-season host for insects and diseases (particularly rusts); these pose a threat to future crops and can be expensive to control later in the season (Photo 5).

Photo 5: *Broad-leafed weeds and grasses form a green bridge in paddock.*

Source: DAFWA

Key points for control of the green bridge:

- Outright kill of the weeds and volunteers is the only certain way to stop them from hosting diseases and insects.
- Diseases and insects can quickly spread from the green bridge, jeopardising crops and current control methods, including the effectiveness of chemicals and genetic breeding for resistance.
- Effective control of pest and disease risks requires neighbours to work together to eradicate weeds and crop volunteers simultaneously.
- Weed growth during summer and autumn depletes soil moisture and nutrients that would otherwise be available to following crops and can have an allelopathic effect. [34]

VIDEOS

WATCH: GCTV5: Managing summer fallow.

MORE INFORMATION

Green bridge management fact sheet

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

Summer weeds - DAFWA

33 Peltzer S, Douglas A, Borger C. (2016). Summer Weeds. Department of Agriculture and Fisheries Western Australia. https://www.agric.wa.gov.au/postharvest/summer-weeds?page=0%2C0

34 GRDC (2009) Green bridge—The essential crop management tool —green bridge control is integral to pest and disease management. Green Bridge Fact Sheet, GRDC Fact Sheet, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/01/grdc-fs-greenbridge

1.3.3 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. [35]

For more information on managing weeds, see Section 6: Weed control.

1.3.4 Stubble retention

Key points:

- Triticale stubble is coarser than either wheat or barley. [36]
- Retaining stubble has several advantages to soil fertility and productivity.
- Retaining stubble can decrease erosion and increase soil water content.
- Benefits of stubble retention are enhanced by reduced tillage and leguminous crop rotations.

Historically, stubble has been burnt because it creates easier passage for seeding equipment, enhances seedling establishment of crops, and improves control of some soil-borne diseases and herbicide resistant weeds. However, the practice of burning stubble has recently declined due to concerns about soil erosion, loss of soil organic matter and air pollution. However, stubble is increasingly being retained which has several advantages of soil fertility and productivity (Photo 6).

Photo 6: *Triticale sown into stubble.*

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

36 Birchip Cropping Group. (2004). Triticale agronomy – 2004. http://www.farmtrials.com.au/trial/13801

Source: Kaspar T in MCCC

Summer rainfall and warmer conditions promote decomposition of stubble.

Reducing erosion risk

One of the main benefits of stubble retention is reduced soil erosion. Retaining stubble decreases erosion by lowering wind speed at the soil surface and decreasing runoff. At least 50% or more ground cover is required to reduce erosion. It is generally considered that 50% ground cover is achieved by 1 t/ha of cereal stubble, 2 t/ha of lupin stubble and 3 t/ha of canola stubble.

Increasing soil water content

A major advantage of retaining stubble is that it increases soil water content by decreasing runoff and increasing infiltration (Figure 4). The actual benefits depend on the timing and intensity of rainfall as well as the quantity and orientation of stubble. Late summer – early autumn rains have more chance of improving the germination and establishment of the next crop. In addition, increased infiltration of water over summer can result in greater nitrogen mineralisation and availability for the subsequent crop.

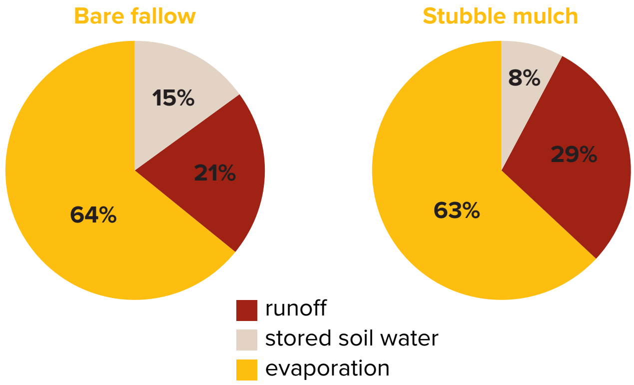


Figure 4: *Retained stubble leads to more stored soil water, mostly due to a reduction in runoff.*

Source: Felton et al. 1987, reproduced in Scott et al. 2010 in Soilquality.org.

Increasing soil carbon

Retaining stubble increases the input of carbon to soil. Stubble is approximately 45% carbon by weight and represents a significant input of carbon to soil. It can take decades for retaining stubble to increase the amount of soil organic carbon. After 10 years, stubble retention generated 2 t/ha more soil organic carbon than stubble burnt plots to a depth of 10 cm in a red chromosol during cropping trials with ley pasture rotations in NSW. After 25 years the inclusion of a clover pasture in the rotation in the same trial had a greater effect on soil organic carbon increases even with tillage compared to stubble retention. Retaining stubble may only increase soil carbon where it is coupled with cultivation but not with direct drilling.

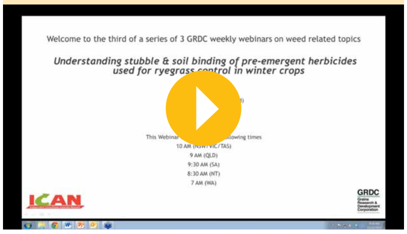
The carbon to nitrogen ratio (C:N) of residues is an important factor in determining the contribution they will make to carbon sequestration as it governs how quickly residues decompose. Pulse residues (C:N 20:1 to 41:1) are more decomposable than cereal residues (C:N 45:1 to 178:1). Faster decomposition may improve nutrient availability for the following crop, but reduce the sequestration of carbon from residues into soil.

VIDEOS

WATCH: Managing Stubble.

WATCH: Stubble height part 1 and part 2.

WATCH: Stubble and soil binding of pre-emergent herbicides for annual ryegrass control in winter crops.



Other benefits of stubble retention

Retaining stubbles returns nutrients to the soil, the amounts depend on the quality and quantity of stubble. Cereal stubble from a high yielding crop may return up to 25 kg of available nitrogen per hectare to the soil. The addition of organic matter with retained stubbles supports soil life, and can improve soil structure, infiltration and water holding capacity. These benefits are greater when integrated no till practices. [37]

Management practices affecting stubble cover

Stubble burning, grazing and cultivation are the main management practices with the potential to reduce stubble cover. A single tillage operation using a chisel plough, for example, can reduce stubble coverage by 30 – 40 % (Table 5).
It is recommended that stubble cover be maintained as long as possible in the fallow, and that planting and fertilising machinery be adapted to minimise disturbance. Where cultivation is required in order to control herbicide resistant weeds, this should be carried out as a one-off operation. [38]

Table 5: *Estimated reduction in cereal stubble cover from different tillage operations (reproduced from Measuring stubble cover: Photo standards for winter cereals).*

Implement	Residue buried by each tillage operation (%)	
	Fresh Stubble	Old (brittle) stubble
Disc Plough	60 – 80	80 – 90
Chisel Plough	30 – 40	40 – 60
Blade Plough	20 – 30	30 – 50
Boomspray	negligible	negligible

Source: Soilquality

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

1.4 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. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half the original amount, what remains can persist for long periods (e.g. sulfonylureas (chlorsulfuron)). This is shown in the Table 6 where known. Herbicides with long residuals can affect subsequent crops, especially if they are effective at low levels of active ingredient, such as the sulfonylureas. On labels, this will be shown by plant-back periods, which are usually listed under a separate plant-back heading or under the 'Protection of crops etc.' heading in the 'General Instructions' section of the label.

Part of the management of herbicide resistance includes rotation of herbicide groups. Paddock history should be considered. Herbicide residues (e.g. sulfonyl urea, triazines etc.) may be an issue in some paddocks. Remember that plant-back periods begin after rainfall occurs. [39]

Table 6: *Residual persistence of common pre-emergent herbicides, and note residual persistence in broad-acre trials and paddock experiences.* [40]

Herbicide	Half-life (days)	Residual persistence and prolonged weed control

37 Soilquality.org. Benefits of retaining stubble – WA. http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble

38 Soilquality.org. Benefits of retaining Stubble – Queensland. http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-in-qld

39 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

40 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

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

For up to date recommendations on herbicide plant-back intervals, visit the AVPMA website.

1.4.1 Conditions required for breakdown

Warm, moist soils are required to breakdown 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 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.

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.

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. [41]

1.4.2 Herbicide residues in soil – an Australia wide study

The move to conservation tillage and herbicide-tolerant crop cultivars means that many farmers are relying on herbicides for weed control more than ever before. Despite the provision of plant-back guidelines on herbicide product labels, site-specific factors such as low rainfall, constrained soil microbial activity and non-ideal pH may cause herbicides to persist in the soil beyond usual expectations. Because of the high cost of herbicide residue analysis, information about herbicide residue levels in Australian grain cropping soils is scarce.

In addition, little is known about how herbicides affect soil biological processes and what this means for crop production. This is especially the case for repeated applications over multiple cropping seasons. In Australia, herbicides undergo a rigorous assessment by the Australian Pesticides and Veterinary Medicines Association (APMVA) before they can be registered for use in agriculture. However, relatively little attention is given to the on-farm soil biology – partly because we are only now beginning to grasp its complexity and importance to sustainable agriculture. Although a few tests are mandatory, such as earthworm toxicity tests and effects on soil respiration, functional services provided by soil organisms such as organic matter turnover, nitrogen cycling, phosphorus solubilisation and disease suppression are usually overlooked.

GRDC co-funded a five year project (DAN00180) to better understand the potential impacts of increased herbicide use on key soil biological processes. This national project, co-ordinated by the NSW Department of Primary Industries with partners in Western Australia (WA), South Australia (SA), Victoria (Vic) and Queensland (Qld), is focussed on the effect of at least six different herbicide classes on the biology and function of five key soil types across all three grain growing regions.

Below are the results of a field survey of herbicide residues in 40 cropping soils prior to sowing and pre-emergent herbicide application in 2015 (Table 7). Recommendations are given to minimise potential impacts of herbicide residues on productivity and soil sustainability.

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

Table 7: *Residue loads (average and maximum) of herbicide active ingredients (a.i.) in the 0–30 cm soil profile of paddocks by region.*

Herbicide	Estimated average load across all sites (kg a.i./ha)*			Estimated maximum load detected (kg a.i./ha)*		
	NSW-Qld	SA	WA	NSW-Qld	SA	WA
AMPA	0.91	0.95	0.92	1.92	1.97	2.21
Glyphosate	0.56	0.48	0.79	2.05	1.05	1.75
Trifluralin	0.08	0.11	0.53	0.14	0.26	1.34
Diflufenican	0.01	0.03	0.04	0.02	0.05	0.09
Diuron	0.14	0.05	0.17	0.16	0.05	0.29
2, 4-D	0.20	0.02	0.01	1.00	0.05	0.02
MCPA	0	0	0	0	0	0
Atrazine	0.02	0.03	0.02	0.03	0.05	0.02
Simazine	0	0.04	0	0	0.05	0
Fluroxypyr	0.03	0	0	0.03	0	0
Dicamba	0	0	0	0	0	0
Triclopyr	0	0.04	0.01	0	0.07	0.01
Chlorsulfuron	0	0	0	0	0	0
Sulfometuron-methyl	0	0	0	0	0	0
Metsulfuron-methyl	0	0	0	0	0	0
Triasulfuron	0	0	0	0	0	0

*Calculated by multiplying mass concentration (mg/kg) detected by area and average bulk density (derived from soilquality.org) for each soil layer

Source: NSW DPI

MORE INFORMATION

Herbicide residues in soils – are they an issue?

Weed control in winter crops.

Conclusions

- Glyphosate, trifluralin and diflufenican are routinely applied in grain cropping systems and their residues, plus the glyphosate metabolite AMPA, are frequently detected at agronomically significant levels at the commencement of the winter cropping season.
- The risk to soil biological processes is generally minor when herbicides are used at label rates and given sufficient time to dissipate before re-application.
- However, given the frequency of glyphosate application, and the persistence of trifluralin and diflufenican, further research is needed to define critical thresholds for these chemicals to avoid potential negative impacts to soil function and crop production. [42]

For more information on herbicide residues, see Section 6: Weed control.

1.5 Seedbed requirements

Seedbed preparation for triticale is very similar to wheat. As with all cereals, triticale should be planted into a firm seedbed and placed near moisture. [43] A good seedbed should be weed, disease and insect free. To minimize weeds, prepare the seedbed so it is as clean as possible before planting, and be sure to practice crop rotation. Planting early will help with the quick establishment of a triticale stand and may stave off early weed pressure. [44]

42 Rose M, Van Zwieten L, Zhang P, Nguyen D, Scanlan C, Rose T, McGrath G, Vancov T, Cavagnaro T, Seymour N, Kimber S, Jenkins A, Claassens A, Kennedy I. (2016). GRDC Update Paper: Herbicide residues in soils – are they an issue? https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/herbicide-residues-in-soils-are-they-an-issue-northern

43 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org

44 UVM. Triticale. Northern grain growers. http://northerngraingrowers.org/wp-content/uploads/TRITICALE.pdf

When shallow seeding, the previous crop's residue will have a greater tendency to interfere with good seed-to-soil contact. Even spreading of the previous crop residue is essential for quick emergence. Make sure seed-to-soil contact occurs. When seeding on summer fallow, take extra care to obtain a firm seedbed to facilitate shallow seed placement into moist soil and to prevent soil erosion by wind.

There are several approaches that can be used in achieving a good seedbed preparation. The deciding factor in choosing approach is how the various techniques manage harvest residues.

The seedbed lays the foundations for crop establishment. However, there are different techniques that can be used to create a seedbed:

- Conventional technique
- Mouldboard ploughing + drilling
- Minimal tillage
- Shallow tillage
- Direct drilling

The technique used depends on many different factors, e.g. harvest residues, the equipment available, soil type, climate, labour requirement, etc (Figure 5).

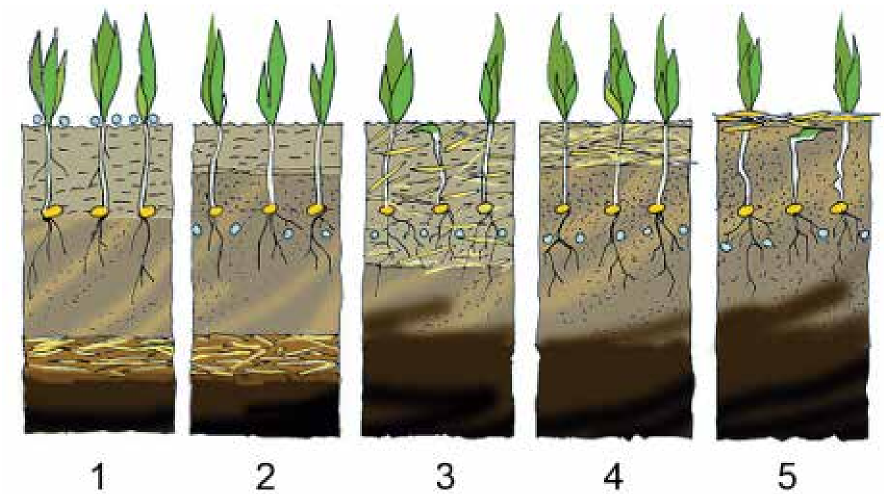


Figure 5: *Diagram demonstrating the results of different seedbed preparation techniques.*

Source: Vaderstad

The seedbed and sowing using different techniques:

1. **Conventional technique** - ploughing in of straw, cultivation to sowing depth with a tine/disc cultivator, conventional drilling, fertiliser spreading.
2. Ploughing in of straw, **shallow cultivation** and drilling, where seed and fertiliser are placed in the soil simultaneously.
3. **Minimal tillage** – tillage of straw by cultivator and drilling, where seed and fertiliser are placed simultaneously in the soil/straw layer.
4. **Shallow tillage –** shallow burial of straw at the surface and drilling, where seed and fertiliser are placed simultaneously in the soil/straw layer.
5. **Direct drilling** – drilling, where seed and fertiliser are placed simultaneously without prior soil tillage. The straw remains on the surface.

Ploughing warms up the soil and buries plant residues so that they do not obstruct sowing. However, ploughing disrupts the soil structure and increases oxidation of the organic material. Without ploughing, the organic material and the soil structure are retained, but the straw can cause problems with sowing and can transmit diseases. [45]

45 Vaderstad. Seedbed Preparation. http://www.vaderstad.com/knowhow/seed-beds/seedbed-creation

Cereals can be conventionally sown or direct drilled into a weed free seedbed from March to mid June.

Pre-irrigation is favoured over 'irrigating up' after sowing, as seeds can swell and burst. Sowing after pre-irrigation should be as soon as soil conditions allow. For an April 1st pre-irrigation, this delay may range from one week on light soils to 3–4 weeks on some heavy clay soils.

Following the initial irrigation, subsequent irrigations should be at a cumulative evaporation less rainfall interval (E-R) of 75 mm on grey soils and 50 mm on red soils.

Pre-irrigation completed by April 1st is a safe option in most years. Later irrigations can cause problems by making the ground too wet for both sowing and grazing.

If not pre-irrigated, then the crop should be sown following sufficient rainfall to wet the soil to 100 mm depth. [46]

1.5.1 Seedbed Soil Structure Decline

Key Points:

- Hard-setting or crusting soils are usually indicators of poor soil structure.
- A 'massive' soil has significantly reduced pore space resulting in poor infiltration and low water holding capacity.
- Bulk density is a good indicator of soil structure.
- Increasing organic matter and decreasing traffic and stock can improve soil structure.
- Gypsum can help in alleviating problems with hard-setting or crusting.

Background

Surface soil structure decline generally results in one of two things – hardsetting or crusting (Photo 7). A surface crust is typically less than 10 mm thick and when dry can normally be lifted off the loose soil below. Crusting forces the seedling to exert more energy to break through to the surface thus weakening it. A surface crust can also form a barrier reducing water infiltration.
Soil structure breakdown caused by rapid wetting can lead to hard-setting. The unstable soil structure once wet, collapses and then shrinks as it dries. This leads to a 'massive' soil layer with little or no cracks and greatly reduced pore space. This hard-set 'massive' structure is associated with poor infiltration, low water holding capacity and a high soil strength. In many instances, this causes patchy establishment and poor crop and pasture growth.

Photo 7: *Soil crusting (left) and cloddy seedbed (right) associated with high concentrations of exchangeable sodium.*

Source: Soilquality.org

46 Agriculture Victoria. Managing winter cereals.

Management to improve seedbed soil structure

To decrease the level of crusting or hard-setting in soils, it is necessary to stabilise soil structure. For example, amelioration of a hard-setting grey clay was found to be most effective using management practices that increased soil organic matter and reduced trafficking, thereby improving soil structure. Removing or reducing stock when the soil is saturated also helps avoid compaction, smearing and 'pugging' of the soil surface.

Another option for stabilising soil structure in soils prone to hard-setting or crusting is through the addition of gypsum on dispersive soils. This effectively displaces sodium, and causes clay particles to bind together helping to create stable soil aggregates. A resulting reduction in the exchangeable sodium percentage (ESP) and increase in the calcium/magnesium ratio may be observed. Addition of lime also adds calcium to the soil, but is generally only used for soils with a low pH. [47]

1.5.2 Tillage

Tillage mixes and buries soil amendments and crop residue, eliminates existing vegetation, reduces pest populations, promotes mineralisation of soil organic matter, and creates a seedbed that facilitates mechanical planting and seed-to-soil contact.

The use of minimum soil disturbance has advantages for the production of triticale. One study noted a slight yield advantage for triticales grown under zero tillage. [48]

Research shows one-time tillage with chisel or offset disc in long-term, no-tillage helped to control winter weeds, and slightly improved grain yields and profitability, while retaining many of the soil quality benefits of no-till farming systems (Photo 8). Tillage reduced soil moisture at most sites; however, this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received after tillage and prior to seeding and during the crop of that year. The occurrence of rain between the tillage and sowing or immediately after sowing is necessary to replenish soil water lost from the seed zone. This suggests the importance of timing of tillage and of considering the seasonal forecast. Future research will determine the best timing for strategic tillage in no-till systems (Photo 9). [49] Note that these results are from one season and research is ongoing, so any impacts are likely to vary with subsequent seasonal conditions.

Photo 8: *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

47 Soilquality.org. Seedbed soil structure decline. www.soilquality.org.au/factsheets/seedbed-soil-structure-decline

48 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org

49 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/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/02/tillage-impact-in-long-term-no-till

VIDEOS

WATCH: Strategic tillage, does no-till mean never till?

MORE INFORMATION

GRDC Strategic Tillage Tips and Tactics fact sheet.

Photo 9: *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

However, tillage can also result in increased soil erosion and surface water eutrophication. During the past 30 years, much progress has been made in reducing tillage. No-tillage crop production has increased 2.5-fold from about 45 million ha worldwide in 1999 to 111 million ha in 2009. One downside of this trend is increased use of herbicides for weed suppression. [50]

In general, pre-plant tillage to prepare the seedbed, control weeds, and disrupt insect and disease life cycles improves crop establishment. However, with cereal rye or other small grains, no-till establishment is an effective option that allows maintenance of the no-till system. Conventional seedbeds are prepared by plowing, disking, and harrowing the soil prior to seeding. Seeding depth depends upon the species being sown. No-till seedings are suitable for highly erodible soils and for late-season establishment. [51]

1.6 Soil moisture

Triticale performs well under rain fed conditions throughout the world and excels when produced under good soil fertility and irrigation. [52] Triticale is grown in areas with an annual average rainfall of about 300 mm through to at least 900 mm. Very little triticale is irrigated. [53]

1.6.1 Dryland

Water availability is a key limiting factor for cereal production in the grainbelt of Australia. Varieties with improved adaptation to water-limited conditions are actively sought and studies have been carried out to identify the physiological basis of the adaptive traits underpinning this advantage.

50 Ryan, M. R., Mirsky, S. B., Mortensen, D. A., Teasdale, J. R., & Curran, W. S. (2011). Potential synergistic effects of cereal rye biomass and soybean planting density on weed suppression. *Weed science*, *59*(2), 238–246.

51 Cover crops for conservation tillage systems. http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/cover-crops-for-conservation-tillage-systems

52 Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org.

53 Cooper KV, Jessop RS, Darvey NL in Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org. http://www.fao.org/docrep/009/y5553e/y5553e00.htm

MORE INFORMATION

Soil water tool - DAFWA

Soil water tool

Plant available soil water graphs show the amount of soil water accumulated from the start of summer (1 November) through the grain growing season and can be used as a tool in the seasonal decision making process.

Plant available soil water is modelled using the Ritchie two-layer fallow evaporation model described in Ritchie, J.T. 1972, Model for predicting evaporation from a row crop with incomplete cover.

While plant available soil water graphs can help create a narrative for the progress of a crop and aid key in-season decision-making, other key factors also need to be considered for any given crop to arrive at an accurate picture. These include:

- Soil status and characteristics including stored soil moisture, soil water-holding capacity and any barriers to infiltration.
- Stored nitrogen and other nutrient availabilities.
- Factors such as non-wetting, water-logging through topography or impermeable layers, leaching or dispersible clays in the soil.

The timing and event intensity of rain during the growing season can also greatly influence the conversion of rainfall to biomass and yield.

To use the soil water tool, select a weather station, a soil type and whether the model is for a fallow or cropped situation from the drop-down lists below. Graphs can be downloaded and saved by clicking on the three horizontal lines to the right of the graph title.

Maps of plant available soil water, updated monthly in the early part of the growing season, can be viewed and downloaded from our Seasonal climate information page. [54]

1.6.2 Irrigation

Irrigation is the artificial application of water to land for the purpose of agricultural production. Effective irrigation will influence the entire growth process from seedbed preparation, germination, root growth, nutrient utilisation, plant growth and regrowth, yield and quality.

The key to maximising irrigation efforts is uniformity. The producer has a lot of control over how much water to supply and when to apply it but the irrigation system determines uniformity. Deciding which irrigation systems is best for your operation requires a knowledge of equipment, system design, plant species, growth stage, root structure, soil composition, and land formation. Irrigation systems should encourage plant growth while minimising salt imbalances, leaf burns, soil erosion, and water loss. Losses of water will occur due to evaporation, wind drift, run-off and water (and nutrients) sinking deep below the root zone.

Proper irrigation management takes careful consideration and vigilant observation.

Irrigation allows primary producers;

- to grow more pastures and crops
- to have more flexibility in their systems/operations as the ability to access water at times when it would otherwise be hard to achieve good plant growth (due to a deficit in soil moisture) is imperative. Producers can then achieve higher yields and meet market/seasonal demands especially if rainfall events do no occur.
- to produce higher quality crops/pastures as water stress can dramatically impact on the quality of farm produce
- to lengthen the growing season (or in starting the season at an earlier time)
- to have 'insurance' against seasonal variability and drought.
- to stock more animals per hectare and practice tighter grazing management due to the reliability of pasture supply throughout the season

54 DAFWA (2016). Soil water tool. https://www.agric.wa.gov.au/climate-weather/soil-water-tool#?station=10115&soil=3&groundCover=1

- to maximise benefits of fertiliser applications. Fertilisers need to be 'watered into' the ground in order to best facilitate plant growth.
- to use areas that would otherwise be 'less productive'. Irrigation can allow farmers to open up areas of their farms where it would otherwise be 'too dry' to grow pasture/crops. This also gives them the capability to carry more stock or to conserve more feed.
- to take advantage of market incentives for unseasonal production
- to have less reliance on supplementary feeding (grain, hay) in grazing operations due to the more consistent supply & quality of pastures grown under irrigation
- to improve the capital value of their property. Since irrigated land can potentially support higher crops, pasture and animal production, it is considered more valuable. The value of the property is also related to the water licensing agreements or 'water right'.
- to cost save/obtain greater returns. The cost benefits from the more effective use of fertilisers and greater financial benefits as a result of more effective agricultural productivity (both quality and quantity) and for 'out of season' production are likely. [55]

MORE INFORMATION

IrrigateWA

Irrigation has also been found to be effective in increasing both shoot Zn content and Zn efficiency of cereal cultivars. It has been suggested that plants become more sensitive to Zn deficiency under rainfed than irrigated conditions. [56]

The main commercial triticale varieties are relatively tall compared with newer wheat varieties, increasing the likelihood of lodging. However, in most of the newer varieties lodging is not considered a problem. The likelihood of lodging is increased by high rates of nitrogen fertiliser and under irrigated conditions (Table 8). [57]

Table 8: *Lodging scores in NVT trials, 2008. NOTE: A score of 0 means the variety was not prone to lodging and a score of 5 means that the variety is prone to heavy lodging.* [58]

Variety	Score
Bogong⚖	0/5
Jaywick⚖	3/5
Tahara	3/5
Tobruk⚖	0/5
Canobolas⚖	0/5
Berkshire⚖	1/5
JRCT 101	0/5
Yukuri	5/5
Rufus	5/5

1.7 Yield and targets

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

55 Agriculture Victoria. About Irrigation. http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/irrigation/about-irrigation

56 Ekiz, H., Bagci, S. A., Kiral, A. S., Eker, S., Gültekin, I., Alkan, A., & Cakmak, I. (1998). Effects of zinc fertilisation and irrigation on grain yield and zinc concentration of various cereals grown in zinc-deficient calcareous soils. *Journal of Plant Nutrition*, *21*(10), 2245–2256.

57 Jessop RS, Fittler M. (2009). Triticale production Manual – an aid to improved triticale production and utilisation. http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

58 Jessop RS, Fittler M. (2009). Triticale production Manual – an aid to improved triticale production and utilisation. http://www.apri.com.au/1A-102_Final_Research_Report_.pdf

The average grain yield of triticale is about 2.5 tonnes/ha, although these yields vary locally from less than 1 tonne/ha in lower rainfall areas and areas with soil problems to more than 7 tonnes/ha in higher rainfall areas with more fertile soils. [59]

In dry springs triticale yields are 10–15% below wheat, due to triticale's longer grain filling period. [60] However, under ideal conditions, researchers have found that triticale can out-yield wheat and barley and sometimes oats. [61]

Observed traits suggested for the higher yields in triticale than wheat include greater early vigour, a longer spike formation phase with same duration to flowering, reduced tillering, increased remobilization of carbohydrates to the grain, early vigorous root growth and higher transpiration use efficiency. [62]

IN FOCUS

Triticale v Durum wheat: a yield comparison in Mediterranean-type environments

The productivity of modern triticales makes them increasingly viable as an alternative small grain cereal crop to durum wheat in the Mediterranean environment. A comparison between the two species was performed, based on a substantial number of cultivars tested in 20 field experiments in Italy. Grain yield per environment ranged from 3.4 to 7.7 t/ha^{-1}; in 11 of the environments, the triticales as a group out-yielded the durum wheats, while in the remaining nine, the two species yielded equally. The superiority of triticale derived from its combination of setting a higher number of grains per unit area (reflecting greater ear fertility) and a similar per unit grain weight. Triticale is well adapted to the Mediterranean environment, provided that sowing density is no less than 300 seeds per m^2, because ear fertility contributes more than tillering capacity to the number of grains set per m^2. In the 20 environments tested, the generally favourable pre-anthesis period in terms of temperature and water availability assured triticale the possibility of realizing a grain yield at least comparable to that of durum wheat. At the same time triticale out-yielded durum wheat when its flowering time fell within an optimal window, and where the post-anthesis environment was not too stressful. High ear fertility should be treated as an important trait in the breeding of small grain cereals, because of its positive influence over both yield potential and yield stability. [63]

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

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

59 Cooper KV, Jessop RS, Darvey NL in Mergoum, M., & Macpherson, H. G. (2004). *Triticale improvement and production* (No. 179). Food & Agriculture Org. http://www.fao.org/docrep/009/y5553e/y5553e00.htm

60 Birchip Cropping Group. (2004). Triticale agronomy – 2004. http://www.farmtrials.com.au/trial/13801

61 Agriculture Victoria (2012). Growing Triticale. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-triticale

62 Bassu, S., Asseng, S., & Richards, R. (2011). Yield benefits of triticale traits for wheat under current and future climates. *Field Crops Research*, *124*(1), 14–24.

63 Motzo, R., Pruneddu, G., Virdis, A., & Giunta, F. (2015). Triticale vs durum wheat: A performance comparison in a Mediterranean environment. *Field Crops Research*, *180*, 63–71.

- Avoiding a failed crop saves money now and saves stored water for future crops. [64]

Estimating crop yields

Accurate, early estimation of grain yield is an important skill. Farmers require accurate yield estimates for a number of reasons:

- Crop insurance purposes
- Delivery estimates
- Planning harvest and storage requirements
- Cash-flow budgeting

Extensive personal experience is essential for estimating yield at early stages of growth. As crops near maturity, it becomes easier to estimate yield with greater accuracy.

Estimation methods

There are many methods available for farmers and others to estimate yield of various crops. Some are straightforward whereas others are more complicated. The method presented in this article is one that can be undertaken relatively quickly and easily Steps are as follows:

1. Select an area that is representative of the paddock. Using some type of measuring rod/tape, measure out an area 1 meter square and count the number of heads/pods.
2. Do this 5 times to get an average of the crop.
3. Count the number of grains in at least 20 heads/pods and average.
4. Using Table 1 below determine the grain weight for the crop concerned and follow through the calculation outlined below

Accuracy of yield estimates depends upon an adequate number of counts being taken so as to get a representative average of the paddock. The yield estimate determined will only be a guide and assumptions made from the estimates contain a degree of uncertainty.

This type of yield estimation is one of the easiest and quickest to complete and should be able to be used in a number of situations on a grain growing property. Grain losses both before and during harvest can be significant and an allowance for 5–10 per cent loss should be included in your final calculations. [65]

Yield Prophet®

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

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

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

Operated as a web interface for APSIM, Yield Prophet generates crop simulations and reports to assist decision-making. By matching crop inputs with potential yield

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

65 Agriculture Victoria. Estimating crop yields; a brief guide. http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide

in a given season, Yield Prophet subscribers may avoid over- or under-investing in their crop.

The simulations provide a framework for farmers and advisers to:

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

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

How does it work?

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

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

MORE INFORMATION

Yield Prophet

1.7.1 Seasonal outlook

Enabling farm businesses to better manage the increasing seasonal variability is critical for the success of the Western Australian agrifood sector. The development of improved weather data and seasonal forecasting tools are designed to assist growers to better manage and take full advantage of the opportunities related to seasonal variability and climate change.

Mobile applications (apps) are providing tools for ground-truthing precision agriculture data. Apps and mobile devices are making it easier to collect and record data on-farm. The app market for agriculture is evolving rapidly, with new apps becoming available on a regular basis. For more information, download the GRDC Update paper, Managing data on the modern farm. [66]

Seasonal Climate Outlook

The Season Climate Outlook (SCO) is a monthly newsletter that summarises climate outlooks for the next three months produced by DAFWA's Statistical Seasonal Forecast (SSF) system specifically for the Western Australian grain belt, and by the Australian Bureau of Meteorology. It provides a review of recent climate indicators, including ENSO (El Niño Southern Oscillation), the Indian Ocean Dipole, the Southern Annular Mode, as well as local sea surface temperature and pressures systems. At appropriate times of year it also includes an overview of the rainfall outlook for the growing season produced by the SSF. [67]

See also, the DAFWA's Seasonal climate information.

66 https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/02/managing-data-on-the-modern-farm

67 DAFWA (2016). Seasonal Climate Outlook. https://www.agric.wa.gov.au/newsletters/sco

CropMate

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

Download CropMate from the App Store on iTunes.

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, and well as El Nino Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather.

Download from the Apple iTunes store or visit the CliMate website.

One of the CliMate tools, 'Season's progress?',uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years.

It explores the readily available weather data, compares the current season with the long-term average, and graphically presents the spread of experience from previous seasons.

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

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

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. [68]

MORE INFORMATION

Australia Bureau of Meteorology Climate outlooks

Climate kelpie.

1.7.2 Fallow moisture

For a growing crop there are two sources of water: first, the water stored in the soil during the fallow, and second, the water that falls as rain while the crop is growing. As a farmer, you have some control over the stored soil water; you can measure how much you have before planting the crop. Long-range forecasts and tools such as the SOI can indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it. [69]

68 Australian CliMate—Climate tools for decision makers, https://climateapp.net.au/

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

HowWet?

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

HowWet?:

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

This information aids in the decision about what crop to plant and how much N fertiliser to apply. Many grain growers are in regions where stored soil water and nitrate at planting are important in crop management decisions.

Questions this tool answers:

How much longer should I fallow? If the soil is near full, maybe the fallow can be shortened.

Given my soil type and local rainfall to date, what is the relative soil moisture and nitrate-N accumulation over the fallow period compared with most years? Relative changes are more reliable than absolute values.

Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply?

Inputs

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

Outputs

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

Reliability

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

Soil descriptions are based on generic soil types with standard organic carbon (C) and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation. [70]

1.7.3 Water Use Efficiency

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

70 Australian CliMate—How Wet/N, https://climateapp.net.au/A04_HowWetN

Triticale uses water more efficiently than oats and rye. [71]

One study found that triticale had similar Water Use Efficiency and resulting yield to wheat under varying soil moisture conditions. [72]

Research in southern Australia found that total water use of triticale was less than that of wheat and rye, particularly at the higher rates of N. WUE of triticale was also higher at all levels of N and increased with increasing N application, whereas the WUE in wheat and rye didn't increase after 50kgN/ha. [73]

One study in a Mediterranean climate attributed high Water Use Efficiency and yield to triticale's stomatal conductance. [74]

IN FOCUS

Triticale grain yield and physiological response to water stress

Water availability in semi-arid regions is increasingly becoming threatened by erratic rains and frequent droughts leading to over-reliance on irrigation to meet food demand. Improving crop Water Use Efficiency (WUE) has become a priority. A two-year study was carried out with four moisture levels, ranging from well-watered (430–450 mm) to severe stress (SS) (220–250 mm), combined with four commercial triticale genotypes grown under field conditions in a hot, arid, steppe climate in South Africa. The results showed that moisture level significantly influenced grain yield and intrinsic WUE in triticale. Well-watered conditions increased grain yield, which ranged from 3.5 to 0.8 t ha−1and4.9–1.8 t ha−1in 2013 and 2014 respectively. Intrinsic WUE increased with decreasing moisture level. Flag leaf photosynthesis and pre-anthesis assimilates contribute much less carbon to grain filling under water stress than previously thought. [75]

CSIRO and research partners, including the GRDC, working on the National Water Use Efficiency (WUE) Initiative have identified ways to improve yield through better WUE, in some cases by as much as 91 per cent. The results of the WUE Initiative have demonstrated an increase in the long term average winter crop yield without increasing input costs, lifting average Australian wheat yield by around 25% across all regions. They have also shown an increase in the long term average yields of winter grain crops including barley and canola. Improved summer fallow management, including weed management and stubble retention can lead to a 60 per cent increase in grain yield. The use of a vetch (legume) break crop following two consecutive grain crops can lead to an increase between 16–83%. The results also revealed that by matching nitrogen supply to the soil type it is possible to achieve a increase of up to 91%. [76]

Water Use Efficiency can be considered at several levels:

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

71 Mergoum *et al*. 2004 – in Tshewang S. (2011). Frost tolerance in Triticale and other winter cereals at flowering. https://e-publications.une.edu.au/vital/access/manager/Repository/une:8821;jsessionid=C91FFA8964B3A49AD3A44FC3BD03EA2E?exact=sm_contributor%3A%22Birchall+C%22

72 Aggarwal, P. K., Singh, A. K., Chaturvedi, G. S., & Sinha, S. K. (1986). Performance of wheat and triticale cultivars in a variable soil—water environment II. Evapotranspiration, Water Use Efficiency, harvest index and grain yield. *Field Crops Research*, *13*, 301–315.

73 Golding, J. B. Restricted tillering in triticale cv. currency-an impediment to grain yield? http://www.regional.org.au/au/asa/1989/contributed/crop/p1-20.htm

74 Motzo, R., Pruneddu, G., & Giunta, F. (2013). The role of stomatal conductance for water and radiation use efficiency of durum wheat and triticale in a Mediterranean environment. *European Journal of Agronomy*, *44*, 87–97.

75 Munjonji, L., Ayisi, K. K., Vandewalle, B., Haesaert, G., & Boeckx, P. (2016). Combining carbon-13 and oxygen-18 to unravel triticale grain yield and physiological response to water stress. *Field Crops Research*, *195*, 36–49.

76 CSIRO. Researching Water Use Efficiency for increased grain yield. http://www.csiro.au/en/Research/AF/Areas/Sustainable-farming/Soil-water-landscape/WUE-Initiative

- Crop WUE is the efficiency with which an individual crop converts water transpired (or used) to grain.
- Systems WUE is the efficiency with which rainfall is converted to grain over multiple crop and fallow.

Ways to increase yield

In environments where yield is limited by water availability, there are four ways of increasing yield:

1. Increase the amount of water available to a crop (e.g. good summer weed control, stubble retention, long fallow, sowing early to increase rooting depth).
2. Increase the proportion of water that is transpired by crops rather than lost to evaporation or weeds (e.g. early sowing, early N, vigorous crops and varieties, narrow row spacing, high plant densities, stubble retention, good weed management).
3. Increase the efficiency with which crops exchange water for carbon dioxide to grow dry matter, i.e. transpiration efficiency (e.g. early sowing, good nutrition, varieties with high transpiration efficiency).
4. Increase the total proportion of dry matter that is grain, i.e. improve the harvest index (e.g. early-flowering varieties, delayed N, wider row spacing, low plant densities, minimising losses to disease, varieties with high harvest index). [77]

The French–Schultz approach

The French-Schultz model is 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.

> *We use a target WUE of 18 kg/ha/mm for wheat. From our benchmarking in 2014 of 149 wheat paddocks, 11% achieved this target, 46% achieved between 13 and 17 kg/ha/mm.*
>
> *A practical WUE equation for farmers to use developed by James Hunt (CSIRO) is: WUE = (yield x 1000) / available rainfall Where avail rain = (25% Nov-Mar rain) + (GSR) – 60 mm evap*

Agronomist's view

The French–Schultz model has been useful in giving growers performance benchmarks. Where yields fall well below these benchmarks, it may indicate something wrong with the crop's agronomy or a major limitation in the environment. There could be hidden problems in the soil such as root diseases, or soil constraints affecting yields. Alternatively, apparent underperformance could be simply due to seasonal rainfall distribution patterns, which are beyond the grower's control. [78]

Modified French-Schultz approach

In Western Australia water evaporation losses can range from 40–90 mm on Mallee soils along the south coast through to 130 mm on the deep sands common at Wongan Hills. WUE and potential yield estimates will be inaccurate if the evaporation component of the French and Schultz equation is not adjusted to suit the agronomic and climatic characteristics of the system being assessed.

77 JB Passioura, JF Angus (2010) Improving productivity of crops in water-limited environments. (Ed. DL Sparks) Advances in Agronomy, Vol. 106, pp. 37–75, Academic Press, http://www.sciencedirect.com/science/article/pii/S0065211310060025

78 GRDC (2009) Water Use Efficiency—Converting rainfall to grain. GRDC Fact Sheet. Water Use Efficiency Fact Sheet, GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/02/grdc-fs-wateruseefficiencysouthwest

VIDEOS

WATCH: GCTV12: Water Use Efficiency Initiative.

WATCH: GCTV10: Grazing stubbles and Water Use Efficiency.

MORE INFORMATION

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

Making the most of available water in wheat production.

The French and Schultz equation has been modified in several important ways to adapt it to rainfall patterns and soils of the WA grain belt. The growing season rainfall (GSR) of the 'crop water use' component was changed to be rainfall from the start of May through to the end of October (instead of April-October as used by French and Schultz).

One-third of out-of-season (OSR) (January-April) rainfall in the 'crop water use' component was also included. This accounts for the fact that about 30% of rainfall falling between January-April is still available in the soil by seeding.

A cap on the 'crop water use' component so that it could not exceed the plant available water capacity (PAWC) of the soil was also introduced. This means that the 'crop water use' component cannot be overestimated in higher rainfall years on soils with relatively low capacity to hold water.

Finally, a sliding scale for the soil evaporation component was introduced which is more suited to WA conditions with soil evaporation set at 130 mm when GSR is greater than 180 mm and 90 mm when GSR is less than 180 mm. This ensures that Water Use Efficiency is not underestimated in low-rainfall years.

In the modified French and Schultz equation:

Crop yield = (May-Oct rainfall + 0.3 (Jan-April rainfall)) – soil evaporation

For soil evaporation the following qualifications are used:

- If GSR >180 mm then soil evaporation = 130 mm
- If GSR < 180 mm then soil evaporation = 90 mm
- If GSR+OSR > PAWC then GSR+OSR = PAWC. [79]

The modified French-Schultz equation can result in less variation between actual and potential yield values – most likely due to the cap placed on 'crop water use' relative to soil PAWC. [80]

Challenging the French-Schultz approach

The seasonality of rainfall, together with frost risk, drives the choice of cultivar and sowing date, resulting in flowering time.

Crops are therefore exposed to contrasting climatic conditions during the critical period for grain formation; i.e. a window of ~20 days before and 10 days after flowering, which affects yield potential and WUE.

Understanding how those climatic conditions affect crop processes and how they vary from south to north 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. They advise caution on the use of simple rules of thumb (French–Schultz) for benchmarking WUE, and discuss the importance of more integrative and dynamic modelling approaches to explore alternatives to increase WUE at the single-crop and whole-farming-systems level; i.e. $/ha.mm. [81]

1.7.4 Nitrogen use efficiency

Key points:

- Improving NUE begins with identifying and measuring meaningful NUE indices and comparing them with known benchmarks and contrasting N management tactics.

79 Oliver Y.M., Robertson M.J., Stone P.J., Whitbread A. (2009) Improving estimates of water-limited yield of wheat by accounting for soil type and within-season rainfall. Crop and Pasture Science 60, 1137–1146.

80 DAFWA. The Agronomy Jigsaw.

81 Rodriguez (2008) Farming systems design and Water Use Efficiency (WUE). 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

- Potential causes of inefficiency can be grouped into six general categories. Identification of the most likely groups is useful in directing more targeted measurement and helping identify possible strategies for improvement.
- As result of seasonal effects, NUE improvement is an iterative process therefore, consistency in investigation strategy and good record keeping are essential. [82]

Nitrogen use efficiency (NUE) is the efficiency with which soil nitrate-N is converted into grain N. The nitrate-N comes from fertiliser, crop residues, manures, and soil organic matter, but it is the efficiency of conversion of fertiliser into grain that is generally of greatest concern to growers. Efficiency is reduced by seasonal conditions, crop diseases, losses of N from the soil as gases, N leaching or immobilisation of N into organic forms.

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

A balance of nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients P and N. Lack of other essential plant nutrients may also limit production in some situations. Knowledge of the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand. [83]

Nitrogen fertilisers are a significant expense for broadacre farmers so optimising use of fertiliser inputs can reduce this cost. There are four main sources of nitrogen available to crops: stable organic nitrogen, rotational nitrogen, ammonium and nitrate. To optimise plants' ability to use soil nitrogen, growers should first be aware of how much of each source there is. The best method of measuring these nitrogen sources is soil testing. [84]

Recent research in the UK found that triticale had higher biomass and straw yields, lower harvest index and higher total N uptake than wheat. Consequently, triticale had higher N uptake efficiency and higher N use efficiency. [85]

In another study, NUE decreased with increasing N fertiliser rates. At an N supply of 100 kg ha–1 a–1, the NUEs of triticale was 0.14 t dry biomass/kg N. [86]

Optimising nitrogen use efficiency

Nitrogen fertilisers are a significant expense for broadacre farmers so optimising use of fertiliser inputs can reduce this cost. There are four main sources of nitrogen available to crops: stable organic nitrogen, rotational nitrogen, ammonium and nitrate. To optimise plants' ability to use soil nitrogen, growers should first be aware of how much of each source there is. The best method of measuring these nitrogen sources is soil testing. [87]

1.7.5 Double crop options

Double cropping is growing a winter and summer crop following one another.

MORE INFORMATION

The fundamentals of increasing nitrogen use efficiency.

82 Dowling C. (2014). The fundamentals of increasing nitrogen use efficiency. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/02/The-fundamentals-of-increasing-nitrogen-use-efficiency-NUE

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

84 Soilquality.org. Optimising soil nutrition. http://www.soilquality.org.au/factsheets/optimising-soil-nutrition

85 ROQUES, S., KINDRED, D., & CLARKE, S. (2016). Triticale out-performs wheat on range of UK soils with a similar nitrogen requirement. *The Journal of Agricultural Science*, 1–21.

86 Lewandowski, I., & Schmidt, U. (2006). Nitrogen, energy and land use efficiencies of miscanthus, reed canary grass and triticale as determined by the boundary line approach. *Agriculture, Ecosystems & Environment*, *112*(4), 335–346.

87 Soilquality.org. Optimising soil nutrition. http://www.soilquality.org.au/factsheets/optimising-soil-nutrition

Cool-season annual forages such as triticale are well-suited to double cropped forage. [88]

Planting cool-season annuals following grain harvest is an economical way to produce high-quality forage. Two types of cool-season annual forages that are well-suited to produce double-cropped forage are small grain cereal grasses, such as triticale, oats, cereal rye and wheat, and brassicas which include turnip and radish.

For autumn forage, the general concept is to take advantage of the potential growing degree-days following grain harvest. Ideally, planting a forage double-crop would occur as soon as possible following grain harvest since the growing degree days available for plant growth rapidly decline through the late summer into early autumn. The risk of failure increases with later planting dates. However, establishment costs are often low enough for many of these forages that the successful years often outweigh the years in which failure occurs. [89]

For spring forage, the winter cereals triticale, rye and wheat tend to be the best choices.

1.8 Disease status of paddock

Crop sequencing and rotation are important components of long-term farming systems and contribute to the management of soil nitrogen status, weeds, pests and diseases.

In the paddock, considerations include soil moisture levels before planting, current and desired stubble cover, and history of herbicide use and history of diseases.

Crop sequencing is only a part of the integrated management of diseases. Other practices include maintaining sufficient distance from last year's paddock of the same crop or from a paddock with residue infected with a pathogen of the intended crop; the use of high-quality, fungicide-treated seed; planting within the planting window, variety selection, and in-crop fungicide treatments. [90]

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

Paddock selection is an important consideration for crown rot management, in particular, and growers should select paddocks with a low risk of the disease. Paddock risk can be determined by visually assessing crown rot and root-lesion nematode (RLN; see section below) levels in a prior cereal crop, paying attention to basal browning, and/or having soil samples analysed at a testing laboratory. The presence of spores of tan (yellow) spot is also an important consideration, and effective management of this disease in cereals depends on decisions made before sowing.

1.8.1 Soil testing for disease

In addition to visual symptoms, the DNA-based soil test ("PreDicta B™") can be used to assess the disease status in the paddock. Soil samples that include plant residues should be tested early in late summer to allow results to be returned before seeding. This test is particularly useful when sowing susceptible varieties, and for assessing the risk after a non-cereal crop.

88 NebGuide. Annual cool-season forages for late-fall or early-spring double-crop. http://extensionpublications.unl.edu/assets/pdf/g2262.pdf

89 NebGuide. 2015. Annual cool-season forages for late-fall or early-spring double crop. http://extensionpublications.unl.edu/assets/pdf/g2262.pdf

90 M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers, 13 September 2011.

PreDicta B

Cereal root diseases cost grain growers in excess of $200 million a year in lost production. Much of this can be prevented.

PreDicta B (B = broadacre) is a DNA-based soil testing service that identifies which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding (Photo 10).

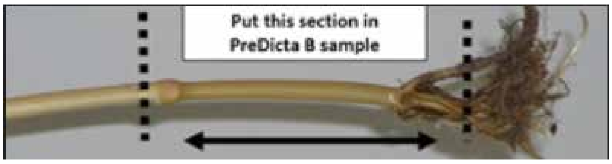


Photo 10: *PreDicta B sample.*

Source: GRDC

PreDicta B includes tests for:

- Take-all (*Gaeumannomyces graminis var tritici (Ggt)* and *G. graminis var avenae (Gga)*).
- Rhizoctonia barepatch (*Rhizoctonia solani AG8*).
- Crown rot (*Fusarium pseudograminearum and F. culmorum*).
- Blackspot of peas (*Mycosphaerella pinodes, Phoma medicaginis var pinodella* and *Phoma koolunga*).

Access PreDicta B testing service

You can access PreDicta B diagnostic testing services through a SARDI accredited agronomist. They will interpret the results and give you advice on management options to reduce your risk of yield loss.

PreDicta B samples are processed weekly between February to mid-May (prior to crops being sown) every year.

PreDicta B is not intended for in-crop diagnosis. See the crop diagnostic webpage for other services.

1.8.2 Cropping history effects

The previous crop will influence levels of both soil- and residue-borne diseases. Important diseases to consider include take-all, crown rot, yellow leaf spot, stripe rust, and wheat streak mosaic virus (Table 9). Transmission from neighbouring paddocks and volunteers are key concerns with some diseases. Controlling the 'green bridge' of over-summering cereals and weeds is an important strategy.

For diseases, there has been a focus on management of crown rot and RLN, yellow leaf spot in winter cereals, and the roles that rotational crops play, particularly the winter pulses. Crop sequences also affect the incidence and severity of major diseases of summer crops, especially those diseases that have several summer, and in some instances winter, crop hosts.

Crop sequencing is only a part of the integrated management of diseases, other practices include maintaining sufficient distance from last year's paddock of the same crop or from a paddock with residue infected with a pathogen of the intended crop, the use of high-quality, fungicide-treated seed, planting within the planting window, variety selection, and in-crop fungicide treatments. [91]

Paddock histories likely to result in high risk of disease e.g. crown rot include:

- durum wheat in the past 1–3 years

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

- winter cereal or a high grass burden from last season—crown rot fungus survives in winter cereal residues, dense stubble cover or where dry conditions have made residue decomposition slow
- break crops, which can influence crown rot in cereals by manipulating the amount of nitrogen (N) and moisture left in the soil profile
- paddocks that have high levels of N at sowing and/or low stored soil moisture at depth. [92]
- wheat varieties grown in previous year (Photo 1). [93]

Photo 11: *Diseased patches from previous crops vary in size from less than half a metre to several metres in diameter.*

Source: DAFWA

For more information, see Section 9: Diseases.

1.9 Nematode status of paddock

Three major root lesion nematode (RLN) species (*Pratylenchus neglectus*, *P. teres* and *P. thornei*) are found in 5.3 million hectares (or about 60%) of WA's cropping area. Populations are yield-limiting in at least 40% of cropping paddocks (Photo 12). [94]

92 GRDC (2009) Crown rot in cereals. GRDC Fact Sheet May 2009, https://grdc.com.au/__data/assets/pdf_file/0021/210918/grdc-crown-rot-fact-sheet-southern-and-western-regions.pdf.pdf

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

94 Collins S, Wilkinson C, Kelly S, Hunter H and DeBrincat. (2014). Root lesion nematode has a picnic in 2013). DAFWA. http://www.giwa.org.au/pdfs/2014/Presented_Papers/Collins%20Sarah_Root%20lesion%20nematode%20has%20a%20picnic%20in%202013_PAPER%20DR.pdf

Photo 12: *Paddock showing patches caused by root lesion.*

Source: DAFWA

Roots of triticale in nematode infested soil have been found to contain fewer nematodes than other cereals. Triticale is thus a useful rotational crop for areas infested with the root lesion nematode. [95]

1.9.1 Nematode testing of soil

PreDicta B

Cereal root diseases cost grain growers in excess of $200 million a year in lost production. Much of this can be prevented.

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

PreDicta B includes tests for:

- Cereal cyst nematode (*Heterodera avenae*).
- Root lesion nematode (*Pratylenchus neglectus and P. thornei*).
- Stem nematode (*Ditylenchus dipsaci*).

Access PreDicta B testing service

You can access PreDicta B diagnostic testing services through a SARDI accredited agronomist. They will interpret the results and give you advice on management options to reduce your risk of yield loss.

PreDicta B samples are processed weekly between February to mid-May (prior to crops being sown) every year.

PreDicta B is not intended for in-crop diagnosis. See the crop diagnostic webpage for other services. [96]

95 Vanstone, V., Farsi, M., Rathjen, T., & Cooper, K. (1996). Resistance of triticale to root lesion nematode in South Australia. In *Triticale: Today and Tomorrow* (pp. 557–560). Springer Netherlands.

96 PIR.SA, SARDI. 2016. PreDicta B. http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

MORE INFORMATION

Tips and tactics: Root-lesion nematodes, Western region.

1.9.2 Effects of cropping history on nematode status

Well-managed rotations are vital. Avoid consecutive host crops to limit populations. Choose varieties with high tolerance ratings to maximise yields in fields where root-lesion nematode (RLN) is present. Choose rotation crops with high resistance ratings, so that fewer nematodes remain in the soil to infect subsequent crops.

For more information, see Section 8: Nematode control

1.10 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 resulted in greater diversity of invertebrate species seen in crops. Cultural control methods such as burning, rolling or cultivating stubbles are sometimes needed to compliment chemical and biological controls. [97]

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

Soil insects include:

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

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

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

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

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

1.10.1 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.

The majority of crop monitoring for insect pests is done with a sweep net, or visually. Using a shake/beating tray is another technique. Sampling pastures mostly relies on visual assessment of the sward or the soil below it. The sweep net is the most convenient sampling technique for many insects. The net should be about 38 cm in diameter, and swept in a 180° arc from one side of the sweepers body to the other. The net should pass through the crop on such an angle that it is tilted so that the lower lip travels through the crop marginally before the upper lip. The standard sample is 10 sweeps, taken over 10 paces. This sampling 'set' should be repeated as many times as practicable across the crop, and at no less than 5 locations. After completing the sets of sweeps, counts should be averaged to give an overall estimate of abundance. Sweep nets tend to under-estimate the size of the pest population. Sweep net efficiency is significantly affected by temperature, relative humidity, crop height, wind speed, plant density and the operator's vigour. [98]

Soil sampling by spade

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

Germinating-seed bait technique

Immediately following planting rain:

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

Trials have shown no difference in the type of seed used for attracting soil-dwelling insects. However, use of the type of seed to be sown as a crop is likely to indicate the species of pests that could damage that crop. The major disadvantage of the germinating-grain bait method is the delay between the seed placement and assessment. [99]

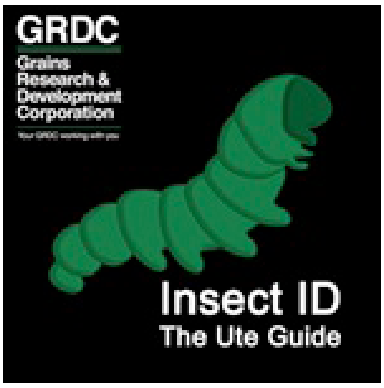
The South Australian Research and Development Institute (SARDI) Entomology Unit provides an insect identification and advisory service. The Unit identifies insects to the highest taxonomic level for species where this is possible and can also give farmers biological information and guidelines for control. [100]

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

99 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/integratedpest-management/help-pages/recognising-and-monitoring-soil-insects

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

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. [101]

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.

See Section 7: Insect control for more information or visit the Pest Genie Australia or APVMA.

1.10.2 Effect of cropping history

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 within a paddock. This will point towards the likely pest issues and allow growers to implement preventive options. [102] 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. [103]

See Section 7: Insect control for more information.

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

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

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