NORTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CEREAL RYE

SECTION 1

PLANNING AND 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 | INSECT STATUS OF PADDOCK

Planning/Paddock preparation

Key messages:

- Relatively inexpensive and easy to establish, cereal rye (*Secale cereale*) outperforms all other cover crops on infertile, sandy or acidic soil or on poorly prepared land. It is widely adapted, but grows best in cool, temperate zones.
- Cereal rye prefers light loams or sandy soils and will germinate even in quite dry soil. It also will grow in heavy clays and poorly drained soils, and many cultivars tolerate waterlogging.
- The optimum pH($CaCl_2$) for cereal rye growth is ~4.5–7.5. [1] It is also tolerant of high levels of aluminium (Al). [2]
- Rye can establish in very cool weather. It will germinate at temperatures as low as ~1°C. Vegetative growth requires ~3°C or higher. [3]
- It is used for early sowings as a dual-purpose cereal, providing abundant, quick, early stock feed, as a grain-only crop, and for erosion control. [4]
- Cereal rye is adapted to all soils; however, its major fit is on the lighter acid soils where yields are usually 70–100% of wheat and triticale when sown between May and June. [5]

1.1 Paddock selection

1.1.1 Disease

Cereal rye is relatively tolerant of many cereal diseases (i.e. take-all, and rusts) making it a useful break crop following grassy pastures. [6]

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 later discussion) levels in a prior cereal crop, paying attention to basal browning and/or having soil samples analysed at a specialised testing laboratory (e.g. Predicta B). The presence of spores of tan (yellow) spot is also an important consideration, and effective management of this disease depends on decisions made before sowing.

Paddock histories likely to result in high risk of disease such as crown rot include:

- durum wheat in the past one to three years
- 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

1 NSW Agriculture (2000) Understanding soil pH. Acid Soil Action Leaflet No. 2. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/167187/soil-ph.pdf

2 B Upjohn, G Fenton, M Conyers (2005) Soil acidity and liming. AgFact AC 19. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/167209/soil-acidity-liming.pdf

3 SARE (2007) Cereal rye. In Managing Cover Crops Profitably, 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

4 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

5 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

6 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

- paddocks that have high levels of N at sowing and/or low stored soil moisture at depth [7]
- wheat varieties grown in previous year (Photo 1). [8]

Photo 1: *Rhizoctonia root rot: Diseased patches from previous crops vary in size from less than half a metre to several metres in diameter.*

Source: Department of Agriculture and Food Western Australia

For more information, see Section 9: Diseases.

1.1.2 Soil

Soil characteristics (surface and subsurface) such as soil pH, sodicity, salinity, acidity, texture, drainage characteristics and compaction will affect choice of crop. Cereal rye is relatively inexpensive and easy to establish, and it outperforms all other cover crops such as wheat on infertile, sandy or acidic soil or on poorly prepared land. [9]

Cereal rye performs well on light loams or sandy soils, and it will germinate even in quite dry soil. It also will grow in heavy clays and poorly drained soils, and many cultivars tolerate waterlogging. [10]

7 GRDC (2009) Crown rot in cereals. GRDC Fact Sheet, May 2009, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2009/05/crown-rot-in-cereals-fact-sheet-southern-western-regions

8 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

9 UVM (2011) Cereal rye. University of Vermont Extension Crops and Soils Team, April 2011, http://northerngraingrowers.org/wp-content/uploads/RYE.pdf

10 SARE (2007) Cereal rye. In Managing Cover Crops Profitably, 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

Cereal rye tolerates high Al levels in acid soils (critical concentration of $CaCl_2$-extractable Al 1.7–2.7 mg/L). [11] Cereal rye is even more tolerant of high Al levels than triticale, also regarded as an acid-soil-tolerant crop choice. [12]

Soil pH

Key points:

- 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.
- Outside of the optimal soil pH range, microelement toxicity damages crops.
- The optimum soil pH($CaCl_2$) for growth of cereal rye is ~4.5–7.5. [13]

Soil pH is influenced by chemical reactions between soil components and water. It is affected by the various 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).

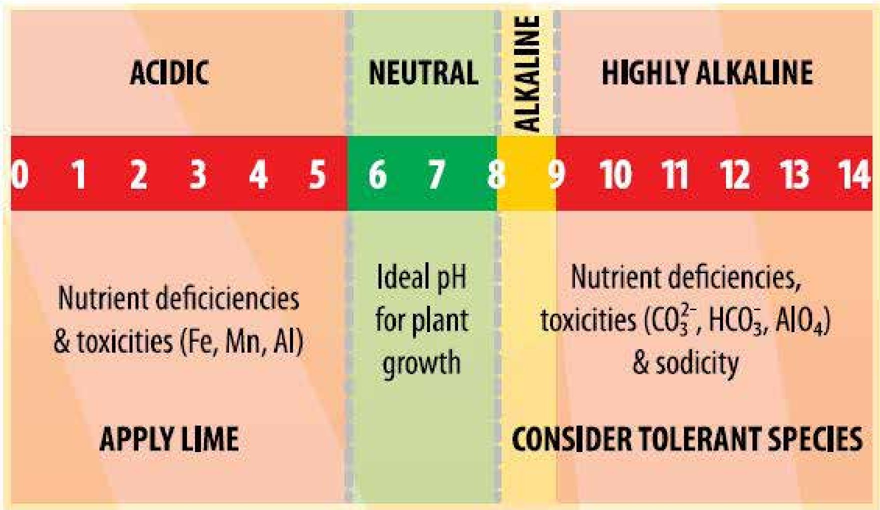


Figure 1: *Classification of soils on the basis of pH (1:5 soil:water), the implications for plant growth and some management options.*

Source: Soil Quality Pty Ltd

More than 500,000 ha of agricultural and pastoral land in Queensland has acidified or is at risk of acidification, and more than half of the intensively used agricultural land in New South Wales (NSW) is affected by soil acidity. Soils most at risk are lighter textured sands and loams with low organic matter levels, and the naturally acidic red clay loam soils commonly found in areas such as the South Burnett and Atherton Tableland. Soils least at risk are the neutral to alkaline clay soils (e.g. brigalow soils and the black clay soils of the Darling Downs and central Queensland).

Acidic soils result in significant losses in production, and where the choice of crops is restricted to acid-tolerant species and varieties, profitable market opportunities may be reduced. In pastures grown on acidic soils, production will be reduced and some legume species may fail to persist.

11 B Upjohn, G Fenton, M Conyers (2005) Soil acidity and liming. AgFact AC 19. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/167209/soil-acidity-liming.pdf

12 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

13 NSW Agriculture (2000) Understanding soil pH. Acid Soil Action Leaflet No. 2, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/167187/soil-ph.pdf

Management of acidic soils

Soil testing

Ideally, soil samples should be taken when soils are dry and have minimal biological activity. Soil samples should be taken from a number of locations across the paddock, as pH may vary from place to place. Samples should be taken at the surface (0–10 cm), and in the subsurface (50–60 cm) to detect subsurface acidity, which may underlie topsoils with an optimal pH. Samples need to be properly located (e.g. GPS) to allow monitoring. Sampling should be repeated every three to four years to detect changes and allow adjustment of management practices.

Farming practices to reduce acidification

Soil acidity must be treated early. If the acidity spreads to the subsoil, serious yield reductions may occur. Subsoil acidity is difficult and costly to ameliorate. Farming practices recommended to minimise acidification include:

- Match N fertiliser inputs to crop demand. Soil testing should be carried out to ensure that fertiliser rates match plant requirements.
- Use forms of N fertiliser that cause less acidification. Table 1 summarises the acidifying effect of different N fertilisers. Nitrate-based fertilisers such as calcium nitrate and potassium nitrate are the least acidifying, but their higher cost limits their use to high value horticultural crops.
- Apply N in split applications, if feasible. Application of a crop's entire fertiliser needs at planting time may contribute to soil acidification by allowing the leaching of nitrate N before the crop roots have developed.
- Sow early after fallow to ensure more rapid utilisation of available N.
- Grow deep-rooting perennial species to take up N from greater depths.
- Regularly apply lime to counter the acidification inherent in the agricultural system.
- Grow acid-tolerant crops or crop varieties more tolerant of acid soils.
- Irrigate efficiently to minimise leaching.

Table 1: *Acidification potential of nitrogen fertilisers assuming that some leaching loss of applied nitrogen occurs.*

Fertiliser	Acidification potential
Calcium nitrate, potassium nitrate	Low
Nitram, urea, animal manure	Medium
Ammonium sulfate, mono-ammonium phosphate (MAP), di-ammonium phosphate (DAP)	High

Source: Soil Quality Pty Ltd

Lime or dolomite application

When soils are too acidic for a particular crop, lime or dolomite can be used to increase soil pH to the desired level. The amount of lime or dolomite required to correct an acidic pH will depend on the soil and the crop.

Soils with high organic matter and clay content will be more resistant to changes in pH and will require higher application rates. To obtain an estimate of the amount of lime required to correct an existing soil acidity problem, a 'lime requirement' or 'buffer pH' soil test should be requested. The test is used to give a lime recommendation to raise the soil pH of the surface 10 cm of one hectare of soil to a target pH that will not limit crop yield. In general, a target pH of 5.5 is suggested.

Once the target soil pH is reached, additional lime or dolomite may be required depending on the crop. The acidifying effect of cropping systems is related to the amount of material removed at harvest, the amount and type of fertilisers normally used and the amount of leaching that occurs. Table 2 gives an indication of the

VIDEOS

WATCH: GCTV8: Liming acid soils.

amount of lime required to counter the inherent acidification associated with some cropping systems. There are opportunities to decrease these lime rates by adjusting N fertiliser rates or form of N fertiliser used. [14]

Table 2: *Lime required to counter the acidification inherent in some cropping systems.*

Cropping system	Lime required (t/ha/year)
Summer crop-winter fallow	0.1
Crop-pasture rotation	0.1
Sugarcane	0.2
Grass pasture for hay production	0.3

Source: Soil Quality Pty Ltd

Cereal rye on erosion-prone soils

Rye has the ability to withstand sand blasts, which enables it to produce a soil-binding cover on land where other cereals will not grow. Under conditions where wheat, oats and barley will grow to only a few centimetres high, or they may even be blown away, rye often will grow vigorously and reach a height of one metre or more.

A further reason for using cereal rye on erosion-prone soils is that its grain and straw are the cereal least preferred by sheep. Sheep provided with more than one choice of stubble within a paddock will preferentially graze other stubbles before they will eat rye stubble.

After the crop is harvested, the tough, resilient stubble is generally left as a protective cover to reduce blowing of the soil and to assist colonisation by other species. Stubble of rye breaks down more slowly than the stubble of other cereals, ensuring soil cover for a long period. [15]

In south-western New South Wales, cereal rye may have a role as a companion crop to cotton for stubble in sandy soils and loams of the lower rainfall area.

Subsoil constraints

Subsoil constraints are chemical, physical or biological properties in the subsoil that limit plant growth. Poor crop growth, despite good starting moisture and adequate in-crop rainfall, may be an indicator of the presence of subsoil constraints. The Northern grains region has generally high soil fertility, although there is increasing evidence that this has been run down over time.

For example, vertosol soils, which occur throughout the north-west of NSW and southern Queensland, are generally well structured and fertile and have pH close to neutral. On these soils, yield is constrained not by surface soil properties, but by subsoil constraints. These include low permeability, shallow rooting depths, sodicity, salinity and toxic concentrations of some elements.

In southern NSW, compaction, acidity and salinity/sodicity may occur and affect crop production. [16]

In the Northern region, both summer and winter crops are important for profit. Much of the region has relatively high seasonal rainfall and production variability compared with the western and southern regions. Much of the region experiences summer-dominant rainfall and grain yield is significantly dependent on conserving soil water from summer rain.

14 Soil Quality Pty Ltd. Soil acidity—Queensland. Soil Quality Fact Sheets, http://www.soilquality.org.au/factsheets/soil-acidity-qld

15 R Sonogan (2013) Growing cereal rye. Agriculture Victoria, May 2013, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-cereal-rye

16 T Swan *et al.* (2011) Production impacts of subsoil constraints on canola productivity in southern NSW. In 17th Australian Research Assembly on Brassicas, http://www.australianoilseeds.com/__data/assets/pdf_file/0009/8298/S6-P2-Swan.pdf

In the Northern grains region, the most significant yield constraints are low nutrient-use efficiency, low water movement through saturated soil (low saturated hydraulic conductivity) and high soil density.

Managing subsoil constraints

Good agronomic management helps to minimise the water and other physiological stresses imposed by subsoil constraints (Table 3). In paddocks where subsoil constraints exist, successful cropping can be achieved by:

- maximising fallow efficiency with short fallows
- ensuring effective weed control
- using suitable rotations that minimise disease
- matching nutrients to realistic yield expectations
- using appropriate species and cultivar selection
- undertaking timely crop sowing.

Table 3: *Some management options for soils with high chloride (Cl) and sodium (Na) concentrations in the top 1 m soil depth.*

Low constraints	Medium constraints	High constraints
(<600 mg Cl, <500 mg Na/kg)	**(600–1200 mg Cl, 500–1000 mg Na/kg)**	**(>1200 mg Cl, >1000 mg Na/kg)**
Use cereal–legume rotation Consider canola if soil profile is full Manage crown rot and nematodes Try opportunity cropping to use available water	Grow tolerant cereals (wheat, barley, canola) Match inputs to realistic yield Consider tolerant cultivars Manage crown rot and nematodes Avoid legumes and durum wheat Try opportunity cropping to use available water	Consider alternative land use (saline forage/pasture production, agro-forestry/ forestry system) Avoid crops or grow tolerant cereals Match inputs to realistic yield

Source: Soil Quality Pty Ltd

Soil testing guide

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.
- When sampling below 10 cm (e.g. 30 cm is required for carbon accounting purposes) stratification by depth increments 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, analysis should be done as soon as possible.

Before deciding how to soil-sample, 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 placed on the information provided (Photo 2). So before you start, define clearly the question you are asking of your soil samples. Consult a professional soil scientist, agronomist or your analytical laboratory to be sure that your soil samples are taken at the right time, from the right depth, the right place, in the appropriate number and are stored in such way that the analysis required is not compromised. If quantitative soil analyses (kg/ha) are required then soil bulk density must also be measured and this requires considerable care. [17]

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: Soil Quality Pty Ltd

1.1.3 Paddocks for forage cereals

If cereal rye is to be used as fodder to provide additional grazing, then a well-drained paddock that can resist pugging damage from stock should be chosen. A paddock of higher fertility that is well drained will provide maximum dry matter production. It is best to select a paddock that has a low level of pasture grasses to avoid the risk of cereal disease transmission, although cereal rye has tolerance to a number of cereal diseases. [18]

1.1.4 Topography

The topographic variations typical of large agricultural paddocks can have a substantial impact on dynamics of soil mineral 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 rye does not result in substantial N reductions, while all cover crops contribute to erosion control and carbon sequestration there. On the other hand, if N leaching is the major concern, low located depression areas are where rye cover crops can be particularly advantageous for scavenging N in the form of nitrate. [19]

---

17 M Unkovich. Soil sampling for soil quality—South Australia. Soil Quality Pty Ltd, http://www.soilquality.org.au/factsheets/soil-sampling-for-soil-quality-south-australia

18 Agriculture Victoria (2008) Establishing forage cereals. Agriculture Victoria, January 2008, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/harvesting-forage-cereals

19 M Ladoni, AN Kravchenko, GP Robertson (2015) Topography mediates the influence of cover crops on soil nitrate levels in row crop agricultural systems. *PloS ONE* 10, e0143358, http://dx.doi.org/10.1371/journal.pone.0143358

IN FOCUS

Topography mediates the influence of cover crops on soil nitrate levels in row-crop agricultural systems

Supplying adequate amounts of soil N for plant growth during the growing season and across large agricultural fields is a challenge for conservational agricultural systems with cover crops. Knowledge about cover-crop effects on N comes mostly from small, flat research plots, and performance of cover crops across topographically diverse agricultural land is poorly understood. Our objective was to assess effects of both leguminous (red clover) and non-leguminous (cereal rye) cover crops on potentially mineralisable N (PMN) and nitrate-N levels across a topographically diverse landscape. This study looked at conventional, low input and organic managements in corn-soybean-wheat rotation. The rotations of low input and organic managements included rye and red clover cover crops. The managements were implemented in twenty large undulating fields in the United States from 2006. Data collection and analyses were conducted during three growing seasons of 2011, 2012 and 2013. Observational micro-plots with and without cover crops were laid within each field on three contrasting topographical positions of depression, slope and summit. Soil samples were collected four to five times during each growing season and analysed for nitrate-N and PMN. The results showed that all three managements were similar in their temporal and spatial distributions of nitrate-N. Red clover cover crop increased nitrate-N by 35% on depression, 20% on slope and 32% on summit positions. Rye cover crop had a significant 15% negative effect on nitrate-N in topographical depressions but not in slope and summit positions (Figure 2). The magnitude of the cover crop effects on soil mineral N across topographically diverse fields was associated with the amount of cover crop growth and residue production. The results emphasise the potential environmental and economic benefits that can be generated by implementing site-specific, topography-driven cover crop management in row-crop agricultural systems. [20]

20 M Ladoni, AN Kravchenko, GP Robertson (2015) Topography mediates the influence of cover crops on soil nitrate levels in row crop agricultural systems. *PloS ONE* 10, e0143358, http://dx.doi.org/10.1371/journal.pone.0143358

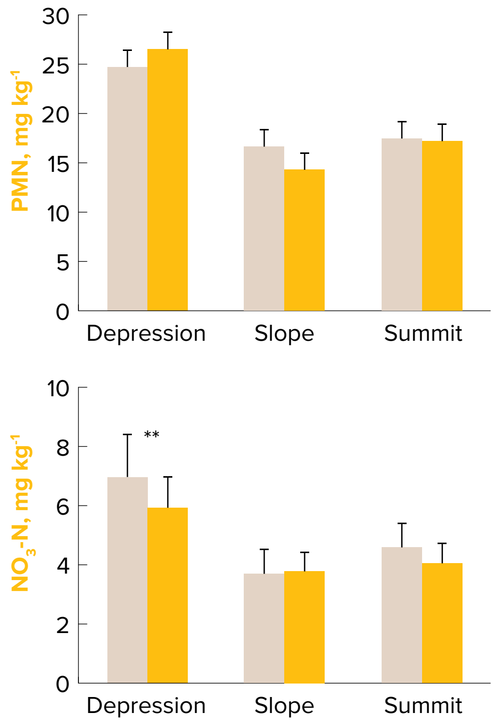


Figure 2: *Soil potential mineralisable N (PMN) and nitrate-N (NO3-N) in bare and cover micro-plots of the studied topographical positions following rye cover crops. Data shown are the averages from 2011, 2012 and 2013 results. Error bars represent standard errors. **Differences between cover and bare micro-plots were statistically significant at P = 0.05.*

Source: figure 2 of Ladoni et al. 2015

1.2 Paddock rotation and history

The hardiest of cereals, cereal rye can be seeded later in autumn than other cover crops and still provide considerable dry matter, an extensive soil-holding root system, significant reduction of nitrate leaching and exceptional weed suppression. Cereal rye has multiple environmental benefits because it can be used for groundcover, reducing wind erosion and increasing soil water retention. [21]

Paddocks with higher fertility are preferred as most crops are sown for the dual purposes of grazing and grain. Cereal rye is often used as a grazed cover crop undersown with subterranean clover pasture on lighter soil types, to provide groundcover while the clover establishes.

Tolerance to take-all disease makes cereal rye suitable for sowing after grassy pastures. This is particularly important in southern NSW, where take-all is a major disease.

21 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group, March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

Cereal rye can be used to build up the fertility of sandy, infertile soils. Few other cool-season green-manure crops are as productive on poor soils. Rye used as a green manure serves as a storehouse of soil nutrients for a following cash crop.

Rye can also improve water quality because the plant's extensive root system can take up excess soil N that might otherwise leach to contaminate groundwater or surface water bodies. This N then slowly becomes available to subsequent crops as the residues gradually decompose. Rye roots can also extract potassium and other nutrients from deep in the soil profile and bring them to the surface, where they become available to subsequent crops. Expect considerable fertility improvement in the topsoil when growing rye. [22]

Rye is one of the best cool-season cover crops for outcompeting weeds, especially small-seeded, light-sensitive annuals. Rye can serve as an overwintering cover crop after maize, or before or after soybeans, fruits or vegetables. If used before a small-grain crop such as wheat or barley, it is important to ensure that no volunteer rye seed remains, which would lower the value of other grains. [23]

Cereal rye is the preferred cereal option for erosion control, withstanding adverse conditions such as cold, waterlogging, low soil pH and drought better than other cereals. Cereal rye has a more extensive root system in the top 30 cm than both wheat and oats. This root system increases soil stabilisation and allows the plant to explore more of the topsoil profile, increasing the plant's tolerance to dry conditions. [24]

Cereal rye's resistance and tolerance to take-all makes it a useful break crop for sowing before susceptible wheat, triticale or barley crops. It can also be sown in situations where take-all is expected—following grassy pasture on soils that are unsuitable for oats. [25]

Although rye is susceptible to the same insects that attack other cereals, serious infestations are rare.

The benefits and disadvantages of cereal rye in a crop rotations are summarised in Table 4.

22 H Valenzuela, J Smith (2002) Rye. Sustainable Agriculture Green Manure Crops, August 2002, University of Hawaii, http://www.ctahr.hawaii.edu/oc/freepubs/pdf/GreenManureCrops/rye.pdf

23 SARE (2007) Cereal rye. In Managing Cover Crops Profitably, 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

24 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

25 Wrighton Seeds. Forage focus—southern green ryecorn. Wrighton Seeds, http://www.pggwrightsonseeds.com.au/products/cereals/southerngreenryecorn/

Table 4: *Benefits and disadvantages of including cereal rye as part of crop rotations.*

Benefits of cropping cereal rye	Disadvantages of cropping cereal rye
Lower input cost than other cereal crops	Low yielding
Provides good ground cover and helps to prevent soil erosion	Difficult to get grain to markets
Taller and quicker growing than wheat, can serve as a windbreak and hold rainfall over winter	Lots of trash, making it difficult to seed through
Can increase soil organic carbon	Can attract armyworms
Establishes well on poor sands	Has a weedy nature—volunteer rye will usually appear for two to three years after a crop has been grown
Extensive root system	
Requires less water than wheat crops	
Can fix up to 45 kg of excess nitrogen	
Increases the availability of exchangeable potassium in the topsoil [26]	
Can attract significant numbers of beneficial insects such as ladybird beetles (coccinellids) [27]	
Resistant to cereal cyst nematodes and a poor host to the RLN (*Pratylenchus neglectus*), providing an alternative management approach for these diseases [28]	

Allelopathic effects

Cereal rye produces several compounds in its tissues and releases root exudates that apparently inhibit germination and growth of weed seeds. These allelopathic effects, together with cereal rye's ability to smother other plants with cool weather growth, make it an ideal choice for weed control (Photo 3).

However, allelopathic compounds may suppress germination of small-seeded vegetable crops as well if they are planted shortly after incorporation of cereal rye residue. Large-seeded crops and transplants are rarely affected. There is some evidence that the amount of allelopathic compounds is lower in tillering plants than in seedlings. [29]

26 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group, March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

27 SARE (2007) Cereal rye. In Managing Cover Crops Profitably. 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

28 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group, March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

29 V Grubinger (2010) Winter rye: a reliable cover crop. University of Vermont, October 2010, https://www.uvm.edu/vtvegandberry/factsheets/winterrye.html

Photo 3: *High level of weed suppression exerted by a rye cover crop.*

Source: Food and Agriculture Organization of the United Nations

1.2.1 Rotation issues

Self-sown cereal rye can be a problem in subsequent cereal crops because of a high level of seed dormancy, so generally it should be sown after other cereal crops. When sown the year before a broadleaf crop such as lupins, volunteer cereal rye can be controlled with herbicides. [30]

In rotations that include a cereal, rye may replace wheat, oats or barley. [31]

The highest yields of rye occur when it is planted on summer fallow. Growing rye repeatedly on the same land increases the chance of ergot (caused by the fungus *Claviceps purpurea*) and some other diseases. A varied crop rotation with less susceptible crops is recommended. [32]

1.2.2 Long fallow disorder

Soils naturally contain beneficial fungi that help the crop to access nutrients such as phosphorus (P) and zinc (Zn) by forming structural associations with the crop root, known as arbuscular mycorrhizae (AM). Many different species of fungi can have this association with the roots of crops, and many of these 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. Long periods of drought have highlighted long fallow disorder, where AM fungi have died out through lack of host plant roots during long fallow periods. As cropping programs restart after dry years, a yield drop is likely due to reduced levels of AM fungi and hence reduced development of AM, making it difficult for the crop to access nutrients. Long fallow disorder is usually typified by poor crop growth. Plants appear to remain in their seedling stages for weeks and development is very slow.

Benefits of AM are:

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

30 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

31 EA Oelke, ES Oplinger, H Bahri, BR Durgan, DH Putnam, JD Doll, KA Kelling (1990) Rye. In Alternative field crops manual. University of Wisconsin and University of Minnesota, https://hort.purdue.edu/newcrop/afcm/rye.html

32 M McLelland, H Brook (2016) Fall rye production. Alberta Government, .http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

In general, the benefits of AM are greater at lower soil P levels because AM increase a plant's ability to access this nutrient. Crop species vary in their dependency on AM for growth. [33]

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, for example, double-cropped from sorghum or cotton, or areas with a sequence of clean winter fallows (Photo 4).

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

Source: Agronomo

Paddocks generally have multiple weed species present at the same time, making weed control decisions more difficult and often involving a compromise after assessment of the prevalence of key weed species. Knowing your paddock and controlling weeds as early as possible are both important for good control of fallow weeds.

Benefits of fallow weed control are significant:

- Conservation of summer rain and fallow moisture (this can include moisture stored from last winter or the summer before in a long fallow) is integral to winter cropping in the Northern region, particularly 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. [34]

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

- Glyphosate-resistant and -tolerant weeds are a major threat to our reduced tillage cropping systems.
- Although residual herbicides will limit re-cropping options and will not provide complete control, they are a key part of successful fallow management.

33 QDAF (2010) Nutrition—VAM and long fallow disorder. Queensland Department of Agriculture and Fisheries, September 2010, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/nutrition-vam

34 GRDC (2012) Summer fallow management. GRDC Fact Sheet, January 2012, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/08/grdc-fs-summerfallowspraying

VIDEOS

WATCH: IWM: Double knock applications—extent of herbicide resistance in the north.

WATCH: GCTV5: Managing summer fallow

- Double-knock herbicide strategies (sequential application of two different weed control tactics) are useful tools but the herbicide choices and optimal timings will vary with weed species.
- Other weed management tactics can be incorporated, e.g. crop competition, to assist herbicide control.
- Cultivation may need to be considered as a salvage option to avoid seed bank salvage. [35]

1.3.1 The green bridge

A green bridge—that is, green weeds and crop volunteers that survive between seasons—provides a between-season host for insects and diseases (particularly rusts); these pose a serious threat to future crops and can be expensive to control later in the season.

Key points for control of the green bridge:

- Outright kill of the weeds and volunteers is the only certain way to avoid them hosting diseases and insects.
- Diseases and insects can quickly spread from the green bridge or summer weeds, 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 also depletes soil moisture and nutrients that would otherwise be available to following crops, and can have an allelopathic effect. [36]

1.3.2 Management strategies

How farming land is managed in the months or years before sowing can be more important than in-crop management in lifting water-use efficiency. 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 soil structure to improve infiltration rates and improve plant access to stored water by removal of compaction zones.

Shorter term management decisions can also have a great impact on how much plant-available water is stored at sowing. These include decisions such as crop sequence or 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 (or not) at critical times.

Many factors influence how much plant-available water is stored in a fallow period; however, good weed management consistently has the greatest impact. [37]

35 R Daniel (2014) Weeds and resistance considerations for awnless barnyard grass chloris and fleabane. GRDC Update Papers, March 2014, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2014/03/weeds-and-resistance-considerations-for-awnless-barnyard-grass-chloris-and-fleabane

36 GRDC (2009) Green bridge fact sheet. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/01/grdc-fs-greenbridge

37 GRDC (2012) Summer fallow management fact sheet. Grains Research and Development Corporation, January 2012, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/08/grdc-fs-summerfallowspraying

1.3.3 Stubble retention

Key points:

- Retaining stubble can decrease soil erosion, increase soil water content and increase soil biological activity.
- Stubble burning, grazing and cultivation are management practices that can decrease stubble cover.
- Where stubble retention is in place, it is important to ensure adequate N availability in order to reach full yield potential.

Historically, stubble has been burnt because it improves weed control and creates easier passage for seeding equipment. However, the practice of burning stubble has declined due to concerns about soil erosion and loss of soil organic matter. Instead of being burnt, stubble is now more commonly retained, which has several advantages for soil fertility and productivity (Photo 5).

In southern NSW, stubble retention is being seen as a priority for farmers and many farmers believe that burning should now only be used strategically. [38]

Photo 5: *Cereal paddock where stubble has been retained, reducing erosion risk and improving fertility.*

Source: Soil Quality Pty Ltd

Reduced erosion risk

One of the main benefits of stubble retention is reduced soil erosion (Figure 3). Retaining stubble decreases erosion by reducing the raindrop energy at the soil surface and decreasing run-off. In order to protect the soil from erosion, crops need to be managed so that at least 30–40% groundcover is maintained throughout the year, especially during the summer months when there is a greater chance of high-intensity rainfall. The amount of cover produced by crops will vary according to seasonal conditions and crop variety. However, as a rule-of-thumb, a 1.5 t/ha grain yield should typically provide 90% stubble cover. This cover may decrease over the fallow period, however, depending on whether the site is subsequently burnt, grazed or cultivated.

38 K Condon (2013) FarmLink. Stubble management practices and research in southern New South Wales. FarmLink Research, http://www.farmlink.com.au/_literature_146390/Stubble_Management_Practices_and_Research_in_southern_NSW

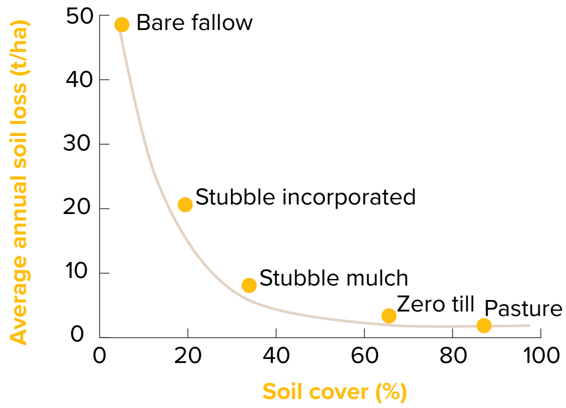


Figure 3: *Soil loss observed depending on the percentage of surface cover from sites on the eastern Darling Downs (from Freebairn 2004).*

Source: Soil Quality Pty Ltd

Increased soil water content

Another advantage of retaining stubble is that it increases soil water content by decreasing runoff, and increasing infiltration (Figure 4). The greater the amount of stubble cover the greater the potential benefits to soil water storage. Stubble coverage of 30% is considered the minimum level required for reducing the effect of soil water runoff. However, stubble coverage of ≥50% will provide further benefit for soil-moisture storage and erosion control.

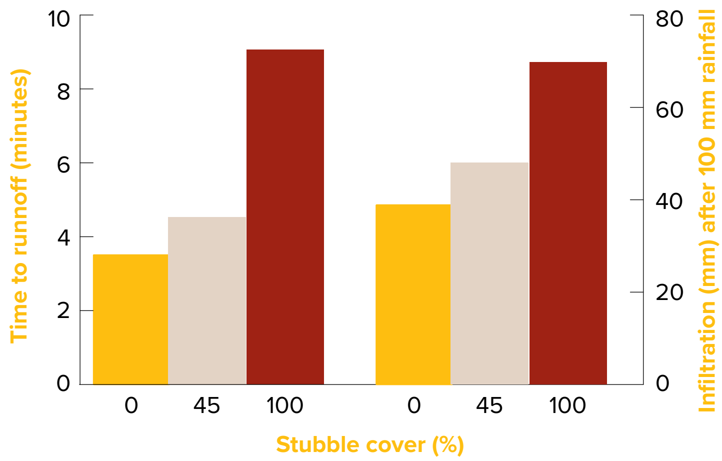


Figure 4: *Influence of different amounts of groundcover from retaining wheat stubble on time to runoff (left) and water infiltration (right) (from Thomas et al. 2008).*

Source: Soil Quality Pty Ltd

Increased biological fertility of soil

Retaining stubble increases the input of carbon to soil. Stubble is ~45% carbon by weight and therefore represents a significant carbon source. Microorganisms in soil require organic carbon to obtain energy. When stubble is retained, the greater inputs of organic carbon increase the number and activity of microorganisms in soil (see Soil

Quality Fact Sheets: Organic carbon pools—Queensland and Microbial biomass—Queensland).

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 to control herbicide-resistant weeds, this should be carried out as a one-off operation. [39]

VIDEOS

WATCH: Burning for weed and snail control

Burning Snails & Weed Seeds

Table 5: *Estimated reduction in wheat or barley stubble cover from different tillage operations (reproduced from Qld Government/Grains BMP: Measuring and managing stubble cover: photostandards 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: Soil Quality Pty Ltd

For more information on weed control strategies, 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 such as chlorsulfuron) (Table 6). 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 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. sulfonylurea, triazines, etc.) may be an issue in some paddocks. Remember that plant-back periods begin after rainfall occurs. [40]

39 Soil Quality Pty Ltd. Benefits of retaining stubble—Queensland. http://www.soilquality.org.au/factsheets/benefits-of-retaining-stubble-in-qld

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

Table 6: *Residual persistence of common pre-emergent herbicides, noting residual persistence in broadacre trials and paddock experiences.*

Herbicide	Half-life (days)	Residual persistence and prolonged weed control
Logran® (triasulfuron)	19	High. Persists longer in high pH soils. Weed control commonly drops off within six weeks
Glean® (chlorsulfuron)	28–42	High. Persists longer in high pH soils. Weed control longer than Logran®
Diuron	90 (range one month to one year, depending on rate)	High. Weed control will drop off within six weeks, depending on rate. Has had observed long-lasting activity on grass weeds such as black/stink grass (*Eragrostis* spp.) and to a lesser extent broadleaf weeds such as fleabane
Atrazine	60–100, up to one year if dry	High. Has had observed long lasting (more than three months) activity on broadleaf weeds such as fleabane
Simazine	60 (range 28–149)	Medium to high. One-year residual in high pH soils. Has had observed long lasting (more than three months) activity on broadleaf weeds such as fleabane
Terbyne® (terbuthylazine)	6.5–139	High. Has had observed long lasting (more than six months) activity on broadleaf weeds such as fleabane and sow thistle
Triflur® X (trifluralin)	57–126	High. Six to eight 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. Three–four months residual
Avadex® Xtra (triallate)	56–77	Medium. Three–four months residual
Balance® (isoxaflutole)	1.3 (metabolite 11.5)	High. Reactivates after each rainfall event. Has had observed long lasting (more than six 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®

Source: Department of Primary Industries NSW

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 a soil temperature range of 18°–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. In addition, where the soil profile is very dry, a lot of rain is required to maintain topsoil moisture for the microbes to be active for any length of time.

Plant-back periods for fallow herbicides in New South Wales

Herbicide plant-back restrictions should be taken into account when spraying fallow weeds prior to sowing winter crops in NSW. Many herbicide labels place time and/or rainfall restrictions on sowing certain crops and pastures after application because of potential seedling damage. Crops such as canola, pulses and legume pastures are the most sensitive to herbicide residues, but cereal crops can also be affected (Table 7).

When treating fallow weeds, especially in late summer or autumn, consideration must be given to the planned crop or pasture for the coming year. In some cases, the crop or pasture for the following year may also have an influence on herbicide choice.

The following points are especially relevant:

- Phenoxy herbicides such as 2,4D ester, 2,4D amine and dicamba, require 15 mm of rainfall to commence the plant-back period when applied to dry soil.
- Group B herbicides such as Ally®, Logran® and Glean® break down more slowly as soil pH increases. Recently applied lime can increase the soil surface pH to a point where the plant-back period is significantly extended.
- Lontrel™, Grazon™ and Tordon™ products break down very slowly under cold or dry conditions, which can significantly extend the plant-back period.

Keeping accurate records of all herbicide treatments and early planning of crop sequences can reduce the chance of crop damage resulting from herbicide residues. [41]

Table 7: *Indicative plant-back intervals for a selection of fallow herbicides in southern New South Wales. For cereal rye, plant-back periods for wheat or barley are a reference point.*

Product	Rate	Plant-back period	Wheat	Barley	Oats	Canola	Legume Pasture	Pulse crops
2,4-D Ester 608*	0–510 ml/ha	(days)	1	1	1	14	7	7
	510–1,150 ml/ha		3	3	3	21	7	14
	1,150–1,950 ml/ha		7	7	7	28	10	21
Amicide Advance 700*	0–500 ml/ha	(days)	1	1	1	14	7	7
	500–980 ml/ha		3	3	3	21	7	14
	980–1,500 ml/ha		7	7	7	28	10	21
Kamba 500*	200 ml/ha	(days)	1	1	1	7	7	7
	280 ml/ha		7	7	7	10	14	14
	560 ml/ha		14	14	14	14	21	21
Hammer 400 EC			No residual effects					
Nail 240 EC			No residual effects					
Goal			No residual effects					
Striker			No residual effects					
Sharpen	26 g/ha	(weeks)	-	-	-	16	-	-
Lontrel	300 ml/ha	(weeks)	1	1	1	1	36	36
Garlon 600		(weeks)	1	1	NS	NS	NS	NS
Ally**		(weeks)	2	6	36	36	36	36
Logran#		(months)	-	-	-	12	12	12

41 RMS (2016). Plant-back periods for fallow herbicides in southern NSW. RMS Agricultural Consultants, http://www.rmsag.com.au/2016/plant-back-periods-for-fallow-herbicides-in-southern-nsw/

Product	Rate	Plant-back period	Wheat	Barley	Oats	Canola	Legume Pasture	Pulse crops
Glean**		(months)	-	9	6	12	12	12
Grazon Extra/Grazon DS		(months)	9	9	NS	9	24	24
Tordon 75D, Tordon 242		(months)	2	2	NS	4	9	6
Tordone Fallow Boss		(months)	9	9	NS	12	20	20

*15 mm rainfall required to commence plant-back period; **, period may extend where soil pH is >7; #, assumes 300 mm rainfall between chemical application and sowing; NS, not specified. Source: RMS Agricultural Consultants

For up-to-date plant-back periods, see the NSW Department of Primary Industries publication: Weed control in winter crops.

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

1.5 Seedbed requirements

The rye paddock should be well prepared and relatively moist for good germination. [42]

Good seed–soil contact is necessary for proper germination and emergence. For best results, plant rye in a firm, well-prepared seedbed.

A good seedbed should be free of weeds, diseases and insects. It should be moist and warm. If rye is grown on light-textured soils that are subject to wind erosion, pre-seeding tillage should be kept to a minimum. To aid erosion control, use implements that will preserve the previous crop residue. Substituting herbicides for cultivation and seeding without pre-seeding tillage (minimum to no till) are other practical options. Under dry or firm soil conditions, seed with seeding implements that minimise soil disturbance, such as air drills with disc or narrow openers, to prevent soil drying.

When shallow seeding, the previous crop's residue will have a greater tendency to interfere with good seed–soil contact. Even spreading of the previous crop residue is essential for quick emergence. 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. [43]

1.5.1 Seedbed soil structural decline

Key points:

- Hard-setting or crusting soils are usually indicators of poor soil structure, which leads to poor water infiltration, poor crop or pasture growth and difficulties when cultivating.
- Where structural decline is due to sodicity, gypsum application can improve soil structure and lead to increased crop yield.
- Increasing soil organic matter and decreasing traffic by stock and machinery can improve soil structure in lighter textured soils.

Decline in surface soil structure generally results in one of two things—hardsetting or crusting (Photo 6). 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 reduce water infiltration and increase runoff.

42 UVM (2011) Cereal rye. University of Vermont Extension Crops and Soils Team, April 2011, http://northerngraingrowers.org/wp-content/uploads/RYE.pdf

43 M McLelland, H Brook (2016) Fall rye production. Alberta Government, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

Breakdown of soil structure caused by rapid wetting can lead to hardsetting. Once soils with an unstable soil structure become wet, they can collapse and then shrink as they dry. This leads to a 'massive' soil layer with little or no cracking and greatly reduced pore space. This hardset, 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. [44]

Photo 6: *Soil crusting (left) and cloddy seedbed (right) associated with high concentrations of exchangeable sodium.*

Source: Soil Quality Pty Ltd

Vertosols in the Northern grains region have good soil structure in their native state. When these soils are brought under cultivation and cropping, soil structure declines because of loss of organic matter, which is the main binding agent for large aggregates (macroaggregates) that provide large pores. If the soil under native state is also sodic, loss of organic matter under cropping and cultivation exacerbates the soil structure decline. [45]

In NSW, soil structure decline is considered an issue for the Tablelands and Western Slopes. [46]

1.5.2 Improving seedbed soil structure

To decrease crusting or hardsetting in soils, it is necessary to stabilise soil structure. On lighter textured soils, this is best achieved by increasing soil organic matter and surface cover and reducing soil traffic (see Soil Quality Fact Sheets: How much carbon can soil store? and Controlled traffic farming—Queensland). Removing or reducing stock when the soil is saturated also helps avoid compaction, smearing and 'pugging' of the soil surface.

Where soils are sodic, the addition of gypsum may help to ameliorate soil dispersion. Gypsum replaces the excess sodium in the soil with calcium, causing clay particles to flocculate and bind together and helping to create stable soil aggregates. In soils with moderate surface sodicity (exchangeable sodium percentage 12), gypsum application at 2.5–5.0 t/ha has been found to improve wheat grain yield significantly in Queensland (Photo 7). [47]

44 Soil Quality Pty Ltd. Seedbed soil structure decline—Queensland, http://www.soilquality.org.au/factsheets/seedbed-soil-structure-decline-queensland

45 R Dalal (2104) Soil structural decline and organic matter in the northern grains region. GRDC Update Papers, August 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Soil-structural-decline-and-organic-matter-in-the-northern-grains-region

46 NSW EPA (2009) Land. Ch. 5. In New South Wales state of the Environment 2009. NSW Environment Protection Agency

47 Soil Quality Pty Ltd. Seedbed soil structure decline—Queensland, http://www.soilquality.org.au/factsheets/seedbed-soil-structure-decline-queensland

Photo 7: *Gypsum application (right) can help treat surface sodicity and improve grain yield under Queensland conditions.*

Source: Soil Quality Pty Ltd

1.6 Soil moisture

1.6.1 Dryland

Water availability is a key limiting factor for crop production in the Northern grains region of Australia.

Rye enhances water penetration and retention. [48]

IN FOCUS

Rye cover crop management influences on soil water, soil nitrate and corn development

Rye can be managed as a cover crop by chemical termination or harvested for forage. A field study was conducted in the United States in 2008 and 2009 to determine the impact of killed *v.* harvested rye cover crops on soil moisture and nitrate-N, and to monitor the impact of the rye on subsequent corn yield. Corn for silage was seeded after winter fallow (control), after a rye cover crop terminated three to four weeks before corn planting (killed rye), or after a rye forage crop harvested no more than two days before corn planting (harvested rye). Soil moisture after killed rye was similar to the control, but after harvested rye was 16% lower. Available soil nitrate-N was decreased after both killed rye (35%) and harvested rye (59%) compared with the control. Corn biomass yield after killed rye was similar to the control, but yield following harvested rye was reduced by 4.5 Mg/ha. Total forage biomass yield (silage + rye) was similar for all treatments. This work demonstrates that the environmental benefits of a winter rye cover crop can be achieved without impacting on corn yield, but the later termination required for rye forage production resulted in soil resource depletion and negatively affected corn silage yield. [49]

48 EA Oelke, ES Oplinger, H Bahri, BR Durgan, DH Putnam, JD Doll, KA Kelling (1990) Rye. In Alternative field crops manual. University of Wisconsin and University of Minnesota, https://hort.purdue.edu/newcrop/afcm/rye.html

49 ES Krueger, TE Ochsner, PM Porter, JM Baker (2011) Winter rye cover crop management influences on soil water, soil nitrate, and corn development. Agronomy Journal 103, 316–323, https://dl.sciencesocieties.org/publications/aj/abstracts/103/2/316?access=0&view=pdf

Tillage practices

Research shows that one-time tillage with chisel or offset disc in long-term no-till helped to control winter weeds and slightly improved grain yields and profitability while retaining many of the soil quality benefits of no-till farming systems. Tillage reduced soil moisture at most sites; however, this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received 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. These results are from one season and impacts are likely to vary with subsequent seasonal conditions. [50]

Limited and strategically timed tillage could have a tactical role as part of a productive, sustainable system. Short-term detrimental effects include reduced protective cover, soil loss, increased runoff, loss of soil carbon and moisture, and reduced microbial; the impacts vary depending on the tillage implement used (Photo 8). In the long term, these effects on soil health and environment are negligible. One-off tillage is potentially a useful management tactic for difficult-to-control and herbicide-resistant weeds (Photo 9). [51]

Photo 8: *Inversion tillage using a mouldboard plough, as pictured here, has more impact than use of a chisel or disc plough.*

Source: Grains Research and Development Corporation, Strategic Tillage Fact Sheet

50 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, February 2013, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Tillage-impact-in-long-term-no-till

51 GRDC (2014) Is there room for strategic tillage in a no-till system? GRDC Strategic Tillage Fact Sheet—Northern and Southern Regions, July 2014, https://grdc.com.au/Resources/Factsheets/2014/07/Strategic-tillage

Photo 9: *Strategic tillage used for control of barnyard grass in fallow.*

Source: Grains Research and Development Corporation, Strategic Tillage Fact Sheet

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 ploughing, discing and harrowing the soil prior to seeding. Seeding depth depends upon the species being sown. No-till seeding is suitable for highly erodible soils and for late-season establishment. [52]

IN FOCUS

Tillage, microbial biomass and soil biological fertility

Key points:

- An experiment tested the observation by farmers that low-disturbance tillage increases total organic carbon (OC) in soil.
- Rotary tillage decreased total OC and labile OC. Such losses could lead to degradation of soil structure and ultimately to a decline in productivity.
- No-till and conservation tillage increased microbial biomass carbon and microbial activity. This indicates that less intensive cultivation may favour sustained microbial function in soil.
- Although no-till and conservation tillage were similar, they may become different in the longer term.

In the mid-1990s, no-till farmers called for an experiment to test anecdotal reports that low-disturbance tillage increased total OC in soil. A seven-year experiment was conducted on a deep sand property in Western Australia using lupin–wheat rotation. The experiment compared the effect of three tillage types on total OC, soil microorganisms and crop yields:

- no-till—no soil disturbance other than seeding
- conservation tillage—a single pass before seeding with 13-cm-wide tines to a depth of ~7.5 cm

52 W Curran, DD Lingenfelter, L Garling, P Wagoner (2006) Cover crops for conservation tillage systems. Conservation Tillage Series Number Five. Pennsylvania State University, http://extension.psu.edu/plants/crops/soil-management/conservation-tillage/cover-crops-for-conservation-tillage-systems

- rotary tillage—a single intense cultivation, before seeding, to a depth of 8 cm using a rotary hoe.

Total organic carbon

Total OC is a measure of the carbon contained within soil organic matter. Low levels can indicate problems with unstable soil structure, low cation exchange capacity and nutrient turnover (see Soil Quality Fact Sheet : Total organic carbon).

After seven years, total OC had increased by 4.4 t/ha under no-till and 2.6 t/ha under conservation tillage (Figure 5), but had decreased by 0.5 t/ha under rotary tillage.

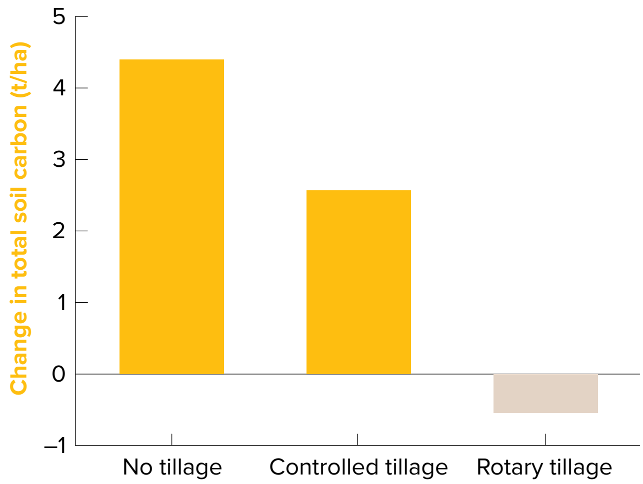


Figure 5: *Change in total soil carbon content at 0–10 cm soil depth between 1998 and 2004 in crops under three tillage regimes. Treatments with different-coloured shading are significantly different (at P = 0.05).*

Source: Soil Quality Pty Ltd

Light-fraction organic carbon

Light fraction OC consists of more recent inputs of organic matter. It responds more quickly to management than total OC and better reflects changes in soil microbiology.

Light fraction OC decreased as tillage became more intensive. By the end of the experiment, light fraction OC in the top 10 cm was 0.83 t/ha under no-till, 0.73 t/ha under conservation tillage and 0.46 t/ha under rotary tillage.

This may indicate that less intensively tilled soils are more biologically active and have higher potential for nutrient turnover and that total OC will increase further in the future.

Soil microorganisms

Soil microbial biomass carbon (see Soil Quality Fact Sheet: Microbial biomass) at 0–5 cm soil depth decreased under rotary tillage compared with no-tillage and conservation tillage (Figure 6).

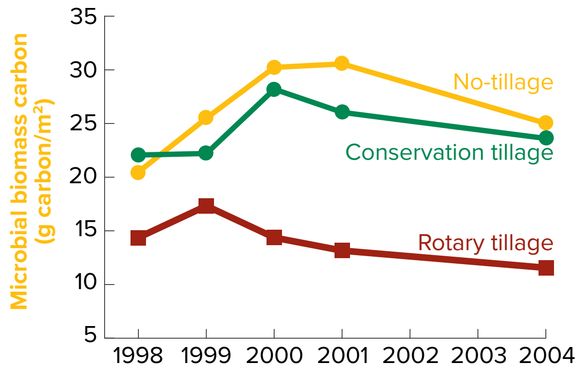


Figure 6: *Microbial biomass carbon in 0–5 cm depth of cropped soil under three tillage regimes.*

Source: Soil Quality Pty Ltd

Microbial biomass N was also higher under no-till and conservation tillage than under rotary tillage. By the end of the experiment, microbial biomass N under no-till and conservation tillage was 31% higher than under rotary tillage.

Tillage decreased microbial activity in soil. The activity of the microbial enzyme cellulase in 0–5 cm soil depth was higher under no-till and conservation tillage than rotary tillage (Figure 7).

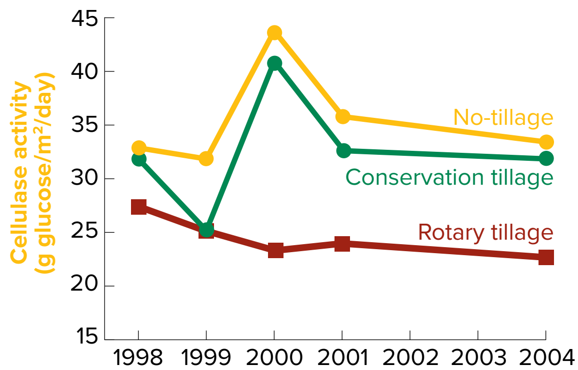


Figure 7: *Activity of the microbial cellulase in 0–5 cm depth of cropped soil under three tillage regimes.*

Source: Soil Quality Pty Ltd

Crop yields

Tillage practice affected crop yields in only one year of the trial, 2003, when lupin grain yields were higher under no-till (2 t/ha) and conservation tillage (1.9 t/ha) than under rotary tillage (1.6 t/ha).

Although tillage did not affect wheat grain yield, it did affect the incidence of Rhizoctonia bare patch. Wheat plants grown under both no-tillage and conventional tillage were more visibly affected by Rhizoctonia bare patch than wheat plants grown under rotary tillage. [53]

53 M Roper, J Carson, D Murphy Tillage, microbial biomass and soil biological fertility. Soil Quality Pty Ltd, http://www.soilquality.org.au/factsheets/tillage-microbial-biomass-and-soil-biological-fertility

1.6.2 Irrigation

Even in areas of relatively high and reliable rainfall such as the north coast of NSW, rainfall patterns do not match the water requirements of many of our commercial crops.

North-coast spring tends to be dry, but this is when many crops need water to guarantee yield and quality. Light rainfall is not effective because most of the water evaporates quickly from the soil surface.

Efficient irrigation reduces operating costs because less water has to be pumped for a given yield. It also means that on-farm dams can be smaller because less water is needed, an important consideration with restricted access to rivers.

Inefficient irrigation can lead to water and nutrients draining through the root-zone, which is a waste of water and fertilisers and leads to rising and contaminated water tables. Inefficient water use can also mean unnecessary pumping from rivers. [54]

MORE INFORMATION

NSW DPI publication: Irrigation essentials for North Coast farmers in NSW.

Irrigating winter cereals in the Northern region

Research and extension projects were undertaken between 2007 and 2011 in partnership between: NSW Department of Primary Industries (NSW DPI), Cotton Catchment Communities CRC, DAFF Queensland, Grains Research & Development Corporation (GRDC), CSIRO, the Foundation for Arable Research (NZ) and Griffiths Agriculture. Before 2007, very little research had been done to develop management guidelines for irrigated cereal crops in the northern region. The following recommendations have been made to optimize irrigated cereal crops in the Northern region.

Soil-N Level

It is essential to conduct a nitrogen soil test in April/May before sowing. Long fallow paddocks with high soil-N require careful management of canopy growth from establishment to avoid lodging.

Row spacing

30 cm row spacing is ideal (6 rows on a 1.8 metre bed). 15 cm or 45 cm row spacing (4 or 12 rows on a 1.8m bed) have, in small plot trials, yielded significantly less than 30 cm spacing.

Plant population

A population of 100-150 plants per square metre of bed or hill area is ideal in the northern region. Low plant populations of 50-100 plants per square metre of bed can achieve high yield levels but plants do not establish evenly.

Seedbed preparation

Seedbed preparation has a significant impact on seedling emergence and therefore yield potential. Planting into adequate soil tilth is critical. Tillage is required to prepare a new seedbed that is free from clods and stubble. The type of machinery used and the number of cultivations depends on the soil type and its structure. Prepare a seedbed that is in optimum condition for seed placement and emergence.

Plant establishment

Once bed preparation has been completed the best establishment scenario is a rain event that will provide sowing moisture, initiate seed germination and seedling. This scenario is ideal in that it provides the best opportunity to achieve high yields (particularly if starting soil N levels are low). In this situation, a uniform plant stand can be achieved; and the grower can then manage early season canopy growth and allow an irrigation to ensure secondary root development.

54 R Swinton, G Creighton (2009). Irrigation essentials for North Coast farmers in NSW. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/349705/Irrigation-essentials-for-North-Coast-farmers-in-NSW.pdf

Pre-irrigation is risky due to the need to delay sowing if rain occurs. However, establishment may be better in a pre-irrigated paddock than a paddock that is dry-sown and watered-up. If the profile is completely dry at sowing the only option is to plant shallow and water-up. This is the least desirable option, particularly if starting soil-N levels are very high. Often, in the water-up situation, plants still do not achieve secondary root growth and require further irrigation during tillering, which may create excessive early season biomass. This can create a crop that is predisposed to lodging, particularly if the starting nitrogen levels are in excess of the plant's requirements.

Water budgeting

When undertaking a water budget; determine plant available water to a soil depth of 90 cm. To maximise yield the wheat crop (from stem elongation stage) should access its entire soil water requirement from a soil depth of 90 cm only. Depending upon in-crop rainfall, maximum yield may require between 3-5 subsequent spring irrigations.

Secondary root growth

The largest early season issue in the northern growing region is achieving adequate secondary root growth, post-sowing. Soil moisture status should be assessed at 25-30 days after emergence, and if necessary, a winter irrigation applied to ensure healthy secondary root development. However, this is a management technique only to be used in low soil-N paddocks. Early secondary root development will enhance water and nutrient uptake. Dry soil moisture below the sowing depth of seed will prevent the growth of secondary roots.

Spring irrigation

Identify the fields' refill point to schedule irrigations and minimise water stress. Use of soil moisture monitoring equipment is recommended. Soil moisture data will help identify the refill point (usually when 50% of plant's available water has been depleted) and allow irrigations to be timed between stem elongation (GS31) and the mid-dough stage (GS80) to minimise crop stress. At the mid-dough stage, soil moisture needs to be re-assessed to determine if a further irrigation is required. Correct timing of the last irrigation will ensure adequate grain fill and reduce the risk of lodging and harvesting delays.

MORE INFORMATION

Irrigated wheat

Limited water availability

The best timing for a single in-crop irrigation of around 1 ML/ha is at early to mid-stem elongation. Head emergence is the most sensitive growth stage to a short severe water stress, the best timing for a single irrigation is one that spreads available water across 2-3 plant growth stages. [55]

1.7 Yield and targets

Climate, in particular rainfall, in Australia tends to be highly variable; 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.

In cereal rye, 53–58% of total grain yield has been found to be produced by lateral shoots, depending on the cultivar and the growing conditions. [56]

Cereal rye is adapted to all soils; however, its major fit is on the lighter acid soils where yields are usually 70–100% of wheat and triticale when sown between May and June.

On the more traditional wheat soils, cereal rye yields are ~50–70% those of wheat. When sown late (in July) and in dry springs, yields are often less than 50% those of

55 Sykes J. (2012). Irrigated Wheat: Best practices guidelines in cotton farming systems. https://grdc.com.au/resources-and-publications/all-publications/publications/2016/04/irrigatedwheatbestpracticeguidelines

56 K Hakala, K Pahkala (2003) Comparison of central and northern European winter rye cultivars grown at high latitudes. The Journal of Agricultural Science, 141, 169–178.

wheat. Although it heads early, its longer grain-filling period and later maturity limit its performance in the western areas of the NSW grainbelt. [57]

Some characteristics of cereal rye are presented in Table 8.

Table 8: *Typical values for characteristics of cereal rye compared with wheat. Note: The number of seeds per kg will vary according to variety and growing conditions. To check grain bulk density, weight one litre, and this value in kilograms is its density in tonnes per m³.*

	No. of seeds per kg	Volumetric grain weight (kg/hL)	Bulk density		Angle of repose (°)
			(kg/m³)	(t/m³)	
Cereal rye	40,000	71	710	0.71	26
Wheat	34,800	75	750	0.75	27

Source: Department of Primary Industries NSW

Low yields are an issue with cereal rye, and there are several contributing factors. First, spring rainfall can be a limiting factor because rye is generally planted on sandy soils with low water-holding capacity. Second, unlike other cereals, rye needs to be cross-pollinated; this can result in low yields as the often hot temperatures result in the pollen drying out before it can fertilise neighbouring plants. When the plants remain unfertilised, the grain is unable to set properly. A third reason for low yields is that most rye varieties require a long time for grain formation, which means that the grain is often small and shrivelled. [58]

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

- Do a simple calculation to see how much water is needed to achieve this yield. [59]
- Know how much soil water is available (treat this water like money in the bank).
- Think about how much risk your farm can carry.
- Consider how this crop fits into your cropping plan: will the longer term benefits to the system outweigh any short-term losses?
- Avoiding a failed crop saves money now and saves stored water for future crops. [60]

Estimating crop yields

Accurate, early estimation of grain yield is important. 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 the best asset for estimating yield at early stages of growth. As crops near maturity, it becomes easier to estimate yield with greater accuracy.

Estimation methods

Many methods are available for farmers and others to estimate yield of various crops. The method presented here can be undertaken relatively quickly and easily. Steps are as follows:

57 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

58 L Martin (2015) Growing cereal rye to increase carbon and prevent wind erosion. Liebe Group, March 2015, http://www.liebegroup.org.au/wp-content/uploads/2015/03/Case-Study-Jeff-Pearse-March-2015.pdf

59 J Whish (2013) Sorghum yield risk vs starting soil moisture. GRDC Update Papers, August 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/08/Sorghum-yield-risk-vs-starting-soil-moisture

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

1. Select an area that is representative of the paddock. Using a measuring rod or tape, measure out an area 1 m^2 and count the number of heads.
2. Do this five times to get an average for the crop: no. of heads per m^2 (e.g. 200).
3. Count the number of grains in at least 20 heads and work out the average: no. of grains per head (e.g. 24).
4. Determine the 100-grain weight for the crop (in grams) by referring to table 1 in: Estimating crop yields—a brief guide. Or in this case for cereal rye, assume 40,000 seeds per kg, from Matthews and McCaffery (2016, Table 14, p. 27) [61]. Then (1000/40,000) × 100 = 2.5 g.
5. No. of grains per m^2 = no. of heads per m^2 × no. of grains per head; e.g. 200 × 24 = 4800.
6. Yield per m^2 (g) = (no. of grains per m^2/100) × 100-grain weight; e.g. 4800/100 × 2.5 = 120 g
7. Yield (t/ha) = numeric value of yield per m^2/100; e.g. 120/100 = 1.2 t/ha

Accuracy of yield estimates depends upon an adequate number of counts being taken to get a representative average of the paddock. The yield estimate determined will be a guide only.

This type of yield estimation 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% loss should be included in final calculations. [62]

Yield Prophet®

Scientists at the Agricultural Production Systems Research Unit (APRSU) 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 had 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 in a given season, Yield Prophet® subscribers may avoid over-investing 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.

61 P Matthews, D McCaffery, L Jenkins (2016) Winter crop variety sowing guide 2016. NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/winter-crop-variety-sowing-guide

62 Agriculture Victoria (2013) Estimating crop yields: a brief guide. Agriculture Victoria, http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide

MORE INFORMATION

Yield Prophet®

GRDC Update Paper: Optimising performance of current northern cropping farming systems.

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 weather station;
- paddock-specific rainfall data recorded by the user (optional);
- individual crop details; and
- fertiliser and irrigation applications during the growing season.

1.7.1 Seasonal outlook

Queensland

The Monthly climate statement, which interprets seasonal climate outlook information for Queensland, is produced by the Science Delivery Division of the Queensland Department of Science, Information Technology and Innovation (QDSITI). The statement is based on QDSITI's own information and draws on information from national and international climate agencies.

The QDSITI assessment of rainfall probabilities is based on the current state of the ocean and atmosphere and its similarity with previous years. In particular, QDSITI monitors the current and projected state of El Niño–Southern Oscillation (ENSO), referring to information such as Variation of sea-surface temperature from average and the Southern Oscillation Index (SOI). Based on this information, QDSITI uses two systems to calculate rainfall probabilities for Queensland:

- QDSITI's SOI-Phase system produces seasonal rainfall probabilities based on phases of the SOI.
- QDSITI's experimental SPOTA-1 (Seasonal Pacific Ocean Temperature Analysis version 1) monitors Pacific Ocean sea-surface temperatures from March to October each year to provide long-lead outlooks for Queensland summer (November–March) rainfall.

Outlooks based on both the SOI-Phase system and SPOTA-1 are freely available, although a password is required to access the experimental SPOTA-1 information (email: rouseabout@dsiti.qld.gov.au). [63]

Queensland Alliance for Agriculture & Food Innovation produces regular, seasonal outlooks for wheat producers in Queensland. These high-value reports are written in an easy-to-read style and are free.

New South Wales

The Seasonal Conditions Report is issued each month by NSW Department of Primary Industries. It contains information on rainfall, water storages, crops, livestock and other issues. It is available to landholders to help them make informed decisions on how they manage operations, and prepare for seasonal conditions and drought.

Seasonal Conditions Reports are also used by the Regional Assistance Advisory Committee in making recommendations to the NSW Government on potential support for farm businesses, families and communities. [64]

63 QDSITI (2016) Seasonal climate outlook. Queensland Department of Science, Information Technology and Innovation, https://www.longpaddock.qld.gov.au/seasonalclimateoutlook/

64 NSW DPI. Seasonal conditions reports. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/climate-and-emergencies/droughthub/information-and-resources/regional-seasonal-conditions-reports

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 ENSO 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 the season's progress (and starting conditions from *HowWet/N?*), should I adjust inputs?

For inputs, *Season's progress?* asks for the weather variable to be explored (rainfall, average daily temperature, radiation, heat sum with base temperatures of 0, 5, 10, 15 and 20°C), a start month and a duration.

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [65]

1.7.2 Fallow moisture

For a growing crop, there are 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. 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 it is needed. [66]

HowWet?

HowWet? is a program developed by APSRU that uses records from a nearby weather station to estimate how much plant available water 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.

65 MCV (2014) Australian CliMate—climate tools for decision makers. Managing Climate Variability R & D Program, https://climateapp.net.au/

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

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. This is of particular importance to northern Australian grain growers with clay soils where stored soil water at planting can constitute a large part of a crop's water supply.

Questions this tool answers:

- How much longer should I fallow? If the soil is near full, maybe the fallow can be shortened.
- Given the soil type on my farm 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 OC 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. [67]

1.7.3 Water Use Efficiency

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

WUE relies on:

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

One study showed ~30 mm more water use on acidic soils by acid-tolerant cereal rye than wheat from ~70 cm deeper root penetration. [68]

Water is the principal limiting factor in rainfed cropping systems in northern Australia. The objective of rainfed cropping systems is to maximise the proportion of rainfall that crops use, and minimise water lost through runoff, drainage and evaporation from the soil surface and to weeds.

In the north of the Northern grains region, rainfall is more summer-dominant and both summer and winter crops are grown. However, rainfall is highly variable and can range, during each cropping season, from little or no rain to major rain

---

67 MCV (2012) How Wet/N? Managing Climate Variability R & D Program, https://climateapp.net.au/

68 D Tennant, D Hall (2001) Improving water use of annual crops and pastures—limitations and opportunities in Western Australia. Australian Journal of Agricultural Research 52, 171–182, http://www.publish.csiro.au/cp/AR00005

events that result in waterlogging or flooding. In the south of the region, rainfall is winter-dominant.

Storing water in fallows between crops is the grower's most effective tool to manage the risk of rainfall variability, as in-season rainfall alone, in either summer or winter, is rarely enough to produce a profitable crop, especially with high levels of plant transpiration and evaporation.

Fortunately, many cropping soils in the northern grains region have the capacity to store large amounts of water during the fallow. [69]

Definitions and calculation of aspects of WUE are as follows:

- Fallow efficiency (%): the efficiency with which rainfall (mm) during a fallow period is stored for use by the following crop. Calculated as: Fallow efficiency = (change in plant-available water during fallow × 100)/fallow rainfall.
- Crop WUE (kg/ha/mm): the efficiency with which an individual crop converts water transpired (or used) (mm) to grain (kg/ha). Calculated as: Crop WUE = grain yield/(crop water supply – soil evaporation).
- Systems WUE (kg/mm): the efficiency with which rainfall (mm) is converted to grain (kg) over multiple crop and fallow phases. Calculated as: SWUE = total grain yield/total rainfall.

Strategies to increase yield

In environments such as western NSW 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, high transpiration-efficiency varieties).
4. Increase the total proportion of dry matter that is grain, i.e. improve harvest index (e.g. early-flowering varieties, delayed N, wider row spacing, low plant densities, minimising losses to disease, high harvest index).

The last three of these all improve WUE. [70]

VIDEOS

WATCH: GCTV12: Water Use Efficiency initiative.

69 GRDC (2009) Water Use Efficiency fact sheet. Grains Research and Development Corporation, https://grdc.com.au/__data/assets/pdf_file/0029/225686/water-use-efficiency-north.pdf.pdf

70 J Hunt, R Brill (2012) Strategies for improving Water Use Efficiency in western regions through increasing harvest index. GRDC Update Papers, April 2012, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/431280/Strategies-for-improving-water-use-efficiency-in-western-regions-through-increasing-harvest-index.pdf

IN FOCUS

Grain yield and water use: relative performance of winter v. spring cereals in Canada

Changing economic conditions have provided strong incentives for grain producers to choose the most profitable cereal crops to grow. Grain yield and WUE were determined for winter wheat, cereal rye, hard red spring (HRS) wheat, Canada prairie spring (CPS) wheat, amber durum and barley under no-till systems. Over 60% of yield variability existing among site/years was due to water use or evapotranspiration (ET) in semi-arid Canada. Mean grain yield increased by 16.3 kg/ha with each millimetre of increase in ET. Barley produced 3748 kg/ha of grain on average, or 21% more than winter wheat, 27% more than CPS wheat, 39% more than rye or durum and 50% more than HRS wheat. Average yields differed <5% between winter wheat and CPS wheat, but in water-stressed environments, CPS wheat had 19–34% lower grain yield than winter wheat. In one of the five cases where winter wheat was seeded much later than the recommended seeding date, CPS wheat yields were 16% higher than winter wheat. With every millimetre of increased ET, CPS or barley increased grain yield by 22 kg/ha, while winter wheat increased yield by 17 kg/ha. Winter wheat and rye had no yield differences in general, but in more moist environments, winter wheat produced higher (up to 28%) grain yield than autumn rye, and in the year when winter wheat was seeded late, winter wheat yielded 11% lower than rye. As fertiliser N increased from 50 to 100 kg/ha, barley grain yield increased by 347 kg/ha, and durum grain yield increased by only 5 kg/ha. Winter wheat, autumn rye and barley had greater WUE than the other spring cereals, but soil profile (0–120 cm) water in the spring did not differ among crops. [71]

MORE INFORMATION

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

Making the most of available water in wheat production.

1.7.4 Nitrogen-use efficiency

Soil type, rainfall intensity and the timing of fertiliser application largely determine N losses from dryland cropping soils.

In cracking clay soils of the northern grains region, saturated soil conditions between fertiliser application and crop growth can lead to significant losses of N from the soil through denitrification. The gases lost in this case are nitric oxide (NO), nitrous oxide (N_2O) and di-nitrogen (N_2). Isotope studies have found these losses can be >30% of the N applied. Direct measurements of nitrous oxide highlight the rapidity of loss in this process.

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 were generally <15% of the N applied, even less in in-crop situations. An exception occurred with the application of ammonium sulfate 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. [72]

71 YT Gan, GP Lafond, WE May (2000) Grain yield and water use: relative performance of winter vs. spring cereals in east-central Saskatchewan. Canadian *Journal of Plant Science* 80, 533-541, https://www.researchgate.net/publication/276030513_Grain_yield_and_water_use_Relative_performance_of_winter_vs_spring_cereals_in_east-central_Saskatchewan

72 G Schwenke, P Grace, M Bell (2013) Nitrogen-use efficiency. GRDC Update Papers, July 2013, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Nitrogen-use-efficiency

In southern NSW, experiments showed that banding of anhydrous ammonia or urea fertiliser provided a slow-release form of N to wheat crops, thereby reducing excessive seedling growth and the risks of haying-off. Yield responses to applied N were small or negative in a drought year but larger (17 kg grain/kg N fertiliser) in favourable seasons. Gaseous loss of ammonia to the atmosphere was negligible. [73]

IN FOCUS

Environment and genotype influence on grain protein concentration of wheat and rye

Protein is a primary quality component of cereal grains. Protein concentration is influenced by both environmental and genotypic factors that are difficult to separate. Cultivar and agronomic trials were conducted on several Saskatchewan (Canada) soil types with the objective of characterising the influence of genotype and environment on wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) grain protein concentration and N-use efficiency (NUE) for grain protein production. Minimum protein concentration of 95.4 g protein per kg dry grain was expressed when cultivars were produced under high productivity conditions on soils with low total plant available N. Minimum protein concentration was maintained until N was no longer the factor most limiting grain yield. At this point, the protein concentration–N response curve of a cultivar entered an increased phase. Any environmental (e.g. water or time of N availability) or genotypic factor that increased yield potential also increased the amount of N required to initiate the increase phase of the grain protein concentration N–response curve. Asymptotic maximum protein concentration was determined by both environmental and genotypic factors. Maximum protein concentration at high levels of N varied from 130 to 231 and 107 to 177 g protein per kg dry grain for winter wheat and rye, respectively. At low levels of total available N, the NUE for grain protein production approached 80%. The NUE for grain protein production dropped off rapidly for subsequent increments of N fertiliser, approaching zero for maximum grain yield and reaching zero when maximum grain protein yield was achieved. The end of the increase phase of the protein concentration-N response curve occurred at approximately the same available N level as maximum grain yield. These observations indicate that management systems designed for the production of cereals with high grain protein concentrations will have a very low NUE for grain and grain protein production. [74]

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 three main stores of N within the soil with the potential to supply N to crops: soil organic matter, plant residues, and mineral N (ammonium and nitrate) present in the soil. To optimise the ability of plants to use soil N, growers should be aware of how much there is in each store, and soil testing is the best method of measuring these N sources. The results can then be used to determine fertiliser rates with models such as CropARM (previously known as

73 JF Angus, VVSR Gupta, GD Pitson, AJ Good (2014) Effect of banded ammonia and urea fertiliser on soil properties and the growth and yield of wheat. *Crop & Pasture Science* 65, 337–352, http://www.publish.csiro.au/cp/CP13337

74 DB Fowler, J Brydon, BA Darroch, MH Entz, AM Johnston (1990) Environment and genotype influence on grain protein concentration of wheat and rye. Agronomy Journal, 82(4), 655–664, https://dl.sciencesocieties.org/publications/aj/abstracts/82/4/AJ0820040655?access=0&view=pdf

WhopperCropper) and The Nitrogen Books (see Soil Quality Fact Sheet: Nitrogen—Queensland). [75]

1.8 Disease status of paddock

Fewer diseases affect rye than other cereals. [76]

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 wheat varieties, and for assessing the risk after a non-cereal crop.

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 is a DNA-based soil testing service that identifies which soilborne pathogens pose a significant risk to broadacre crops prior to seeding.

PreDicta B includes tests for:

- take-all (*Gaeumannomyces graminis var. tritici* and *G. graminis var. avenae*
- Rhizoctonia barepatch (*Rhizoctonia solani AG8*)
- crown rot (*Fusarium pseudograminearum and F. culmorum*)
- blackspot of field peas (*Mycosphaerella pinodes, Phoma medicaginis var. pinodella* and *P. koolunga*).

Access PreDicta B testing service

Growers can access PreDicta B diagnostic testing services through an agronomist accredited by the South Australian Research and Development Institute (SARDI). They will interpret the results and provide advice on management options to reduce the risk of yield loss.

SARDI processes PreDicta B samples weekly from February to mid-May (prior to crops being sown) every year.

PreDicta B is not intended for in-crop diagnosis. See SARDI's Crop diagnostics webpage for other services.

The Queensland Government also has a service: Test your farm for nematodes.

PreDicta B certification courses

SARDI runs one-day courses to:

- certify agronomists in use of the PreDicta B testing service run by SARDI; and
- educate new and experienced agronomists about how better to manage soilborne diseases.

Completing the course will give agronomists:

- access to the PreDicta B service;
- access to the e-version of the Root Disease Risk Management Resource Manual; and
- a PreDicta B soil corer valued at over $100.

Courses focus on the three main diseases in each region, selecting from:

- Rhizoctonia barepatch,

75 Soil Quality Pty Ltd. Optimising soil nutrition—Queensland. http://www.soilquality.org.au/factsheets/optimising-soil-nutrition-queensland

76 SARE (2007) Cereal rye. In Managing Cover Crops Profitably, 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

- RLN,
- crown rot, and
- take-all. [77]

1.8.2 Effects of cropping history

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. 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, the focus in the northern grains region has been 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. [78]

For more information, see Section 9: Diseases.

1.8.3 Nematode status of paddock

Pratylenchus thornei and *Pratylenchus neglectus* (RLN) are migratory root endoparasites that are widely distributed in the wheat-growing regions of Australia and can reduce grain yield by up to 50% in many current wheat varieties (Photo 10). *P. thornei* is the most damaging species and occurs commonly in the northern grain region; *P. neglectus* occurs less frequently than *P. thornei* but is still quite common. A third nematode, *Merlinius brevidens* (stunt nematode), is the most commonly identified plant-parasitic species in this region. [79]

Photo 10: *Paddock showing patches caused by root-lesion nematodes.*

Source: Department of Agriculture and Food WA

77 PIRSA (2016) PreDicta B. Primary Industries and Regions South Australia, September 2016, http://pir.sa.gov.au/research/services/molecular_diagnostics/predicta_b

78 M Ryley (2011) Diseases shared by different crops and issues for crop sequencing. GRDC Update Papers, September 2011, http://elibrary.grdc.com.au/ark!!33517/vhnf54 t/a9ft5hf

79 QDAF (2010) Test your farm for nematodes. Queensland Department of Agriculture and Fisheries, July 2010, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematodes/test-your-farm-for-nematodes

MORE INFORMATION

GRDC Fact Sheet: Plant parasitic nematodes, northern region.

Rye can help reduce root-knot nematodes (*Meloidogyne* spp.) and other harmful nematodes. [80]

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 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

1.9 Insect status of paddock

Rye in the paddock is generally free from insect pests. Where problems arise, growers should contact their local agronomist or state government department of primary industries for advice.

Although rye is susceptible to the same insects that attack other cereals, serious infestations are rare. Rye reduces insect pest problems in rotations and attracts significant numbers of beneficials such as ladybird beetles. [81]

Pests such as redlegged earth mites, blue oat mites, nematodes and, in some seasons, cutworms may pose a risk in some paddocks. Risk should be assessed based on paddock history (including recent control) and crop susceptibility. Controlling weeds in summer fallows and around paddocks can also minimise some of these pests.

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

1.9.1 Insect sampling of soil

Recent seasons have seen seemingly new pests and unusual damage in pulse and grain crops in the Northern grains region. Growers are advised to:

- Monitor crops frequently so as not to be caught out by new or existing pests.
- Look for and report any unusual pests or damage symptoms—photographs are useful.
- Just because a pest is present in large numbers in one year does not mean it will be so the next year. Another spasmodic pest, e.g. soybean moth, may make its presence felt.
- However, be aware of cultural practices that favour pests and rotate crops each year to minimise the build-up of pests and plant diseases. [82]

80 SARE (2007) Cereal rye. In Managing Cover Crops Profitably, 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

81 SARE (2007) Cereal rye. In Managing Cover Crops Profitably, 3rd Edition. Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Nonlegume-Cover-Crops/Cereal-Rye

82 H Brier, M Miles (2015) Emerging insect threats in northern grain crops. GRDC Update Papers, July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Emerging-insect-threats-in-northern-grain-crops

Sampling methods

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 to different sampling techniques.

Sweep net

The majority of crop monitoring for insect pests is done with a sweep net, or visually. Use of 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 sweeper's body to the other. The net should pass through the crop at such an angle 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 five locations. After completing the sets of sweeps, counts should be averaged to give an overall estimate of abundance. Sweep nets tend to underestimate 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. [83]

Soil sampling by spade

Method:

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

Germinating seed bait technique

Immediately following planting rain:

1. Soak insecticide-free crop seed in water for at least two hours to initiate germination.
2. Bury a dessertspoon of the seed under 1 cm of soil at each corner of a square 5 m × 5 m at five widely spaced sites per 100 ha.
3. Mark the position of the seed baits, because 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 that is 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. [84]

1.9.2 Identification

The SARDI Entomology Unit provides an insect identification and advisory service. The Unit identifies insects to the highest taxonomic level for species where possible and can give farmers biological information and guidelines for control. [85]

83 QDAF (2000) Sampling methods for insects and mites. Queensland Department of Agriculture and Fisheries, https://ipmguidelinesforgrains.com.au/ipm-information/making-informed-control-decisions/monitoring/monitoring-tools-and-techniques/

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

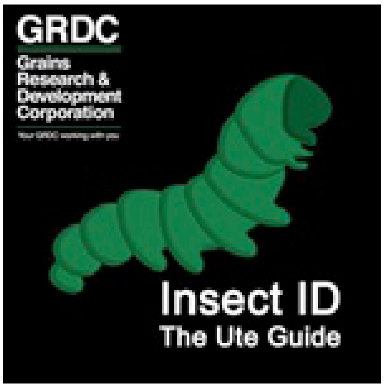
85 PIRSA (2015) Insect diagnostic service. Primary Industries and Regions South Australia, June 2015, http://pir.sa.gov.au/research/research_specialties/sustainable_systems/entomology/insect_diagnostic_service

MORE INFORMATION

Pest Genie Australia

APVMA.

Insect ID: The Ute Guide



The Insect ID Ute Guide, available on Android and iPhone, 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 lifecycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored, and other pests with which they may be confused. Use of this app should result in better management of pests, increased farm profitability and improved chemical usage. [86]

App features:

- region selection
- predictive search by common and scientific names
- ability to compare photos of insects side-by-side with insects in the app
- identification of beneficial predators and parasites of insect pests
- option to download content updates in-app with the latest pests affecting crops for each region
- ensures awareness of international biosecurity pests.

1.9.3 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 to the likely pest issues and allow growers to implement preventive options. [87] 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 ladybird beetles, hoverflies and parasitic wasps. [88]

For more information, see Section 7: Insect control.

Where paddock history, paddock conditions or pest numbers indicate a high risk of pest damage, a grower might decide to use pre-seeding control measures to reduce pest pressure, apply a seed dressing to protect the crop during the seedling stage, and plan to apply a foliar insecticide if pest numbers reach a particular level. [89]

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

86 GRDC (2016) Apps. Grains Research and Development Corporation, https://grdc.com.au/Resources/Apps

87 R Jennings (2015) Growers chase pest-control answers. GRDC Ground Cover Issue 117, June 2015, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-117-July-August-2015/Growers-chase-pest-control-answers

88 P Bowden, P Umina, G McDonald (2014) Emerging insect pests. GRDC Update Papers, July 2014, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Emerging-insect-pests

89 G Jennings (2012) Integrating pest management. South Australian No-Till Farmers Association, Spring 2012, http://www.santfa.com.au/wp-content/uploads/Santfa-TCE-Spring-12-Integrating-pest-management.pdf

- Weedy fallows and volunteer crops encourage soil insect buildup.
- Insect numbers decline during a clean long fallow due to lack of food.
- Summer cereals followed by volunteer winter crops promote the buildup 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-till 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. Because 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. [90]

See Section 7: Insect control, for more information.

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