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GRAINS RESEARCH & DEVELOPMENT CORPORATION

VETCH

SECTION 1

PLANNING AND PADDOCK PREPARATION

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

Planning/Paddock preparation

Key messages

- There are many benefits to including vetch in cropping sequences including; nitrogen fixation and increased weed and pest control options.
- Vetch is sensitive to highly saline, sodic and acidic soils and cannot tolerate long periods (7 days) of waterlogging.
- Vetch should be sown into a clean seedbed, with weeds controlled prior to planting with cultivation and/or herbicides. Post emergent herbicide options for weed control in vetch is limited.
- Vetch is well suited to no-till, standing stubble systems.
- To reduce the risk of disease, vetch should be sown into paddocks only once every four years.
- Caution should be taken that vetch does not carry over to following pulse crops in the rotation. For example, zero tolerance of vetch in lentils.

Vetch can be a valuable addition to continuous cropping systems. The income from vetch hay combined with highly effective non-chemical weed control and water conservation, especially preceding higher value and risky crops such as canola, can make the legume hay crop a good option. However, soil cover is reduced for vetch hay compared with brown manure and this low cover can be an issue with low-biomass grain legumes on erosion-prone areas. [1]

1.1 Paddock selection

Vetches are potentially adapted to most areas of Australian farming land. [2]

The crop is adapted to and grown in most soil types and rainfall areas in southern and Australia, with grain yields similar to pea yields in these areas. It is also grown in New South Wales and southern Queensland (mostly as a green manure).

1.1.1 Rainfall

Vetch is suited to areas with annual rainfall of 300–750 mm (growing season rainfall 200–350 mm). Early flowering varieties (Rasina(b & Langedoc) are suited to lower rainfall zones, and Morava(b and Blanchefleur for higher rainfall zones. These forage vetches can grow successfully in areas of 400 to 650 mm of annual rainfall (Table 1).

Table 1: *Recommended Vetch grain variety according to rainfall zones (mm).*

<350	350–400	400–450	450–600	>600
Rasina(b	Rasina(b	Morava(b	Morava(b	Morava(b
Cummins	Blanchefleur	Rasina(b	Rasina(b	Timok(b
Volga(b	Cummins	Blanchefleur	Timok(b	
Timok(b	Morava(b	Cummins		
	Volga(b	Volga(b		
	Timok(b	Timok(b		

Source: SARDI

1 J Kirkegaard (2017) Careful management required to sustain continuous cropping. GRDC E-Newsletter.

2 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

1.1.2 Soil conditions for vetch production

Soils in the Northern region tend to have a moderate to high percentage of clay and vary in colour from yellow through to red, brown, grey and black. Major soil types are Vertosol, Dermosol, Chromosol, Sodosol, Kandosol and Ferrosol. [3]

Vetch is adapted to a broad range of soils, from acidic granite and sandstone soils through to highly alkaline and/or heavy clay soils (Table 2). It grows better than field peas on more hard-setting soils.

Table 2: *Vetch soil requirements.*

Factor	Vetch adaptation
Soil pH requirement	5.0–9.0
Soil texture	Loamy sand-clay
Drought adaptation strategies	Drought escape
Waterlogging	Sensitive
Boron toxicity/sodicity	Moderately tolerant
Salinity	Moderately sensitive
Surface crusting	Sensitive

Source: B French, P White, 2005

MORE INFORMATION

Soil acidity and liming

Vetch is sensitive to long periods (over 7 days) of waterlogging or saline conditions, and should be grown on well-drained soils. [4] Vetch yield declines when soil ECe is less than 3.0 dS/m. Yield declines at the rate of 11% for each unit increase in ECe. This is because vetch has poor root penetration into sodic soils. [5]

Vetch prefers neutral soils, but can grow in slightly acid (pH 6.3) to alkaline (7.5–7,8pH) soils. [6] Vetch is more tolerant to acid soils than most other legumes.

In trials on alkaline and acid soil types (sandy loam, heavy clay, and non-wetting sand in low to high rainfall areas), vetch showed good tolerance to all soil types over three years. An extra 1 mm of rain was found to produce an extra 18–24 kg of vetch dry matter in these trials. [7]

Vetch does not perform at high levels of exchangeable aluminium in the soil, having a similar tolerance to that of sub clover and white clover, but less than that of serradella. [8]

Lime pelleting at sowing is recommended when planting into acid soils below pH 5.5. [9]

1.1.3 Sodic or dispersive soils

Sodicity is a term given to the amount of sodium held in a soil. Dispersive soils are generally a surface problem, sodicity can be at the surface but also at depth; i.e. plant roots hot this layer and become restricted in growth and cannot extract as much water out of the profile. High sodicity causes clay to swell excessively when wet. The clay particles move so far apart that they separate (disperse). This weakens the aggregates in the soil, causing structural collapse and closing-off of soil pores. For this reason, water and air movement through sodic soils is severely restricted. In crop paddocks, sodic layers or horizons in the soil may prevent adequate water

3 D Herridge. (2011). Managing legume and fertiliser N for Northern grains region. http://www.ini2016.com/pdf-posters/Herridge.pdf

4 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

5 CRDC. Comparative advantages/disadvantages of rotation crops with cotton. http://www.cottoninfo.com.au/sites/default/files/tools/CottonRotation/Rotation_chart_Page_1small.pdf

6 R Matic, S Nagel, G Kirby (2008) Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

7 R Matic (2007) Improved vetch varieties for fodder production. Rural Industries Research and Development Corporation.

8 NSW DPI. Namoi Woolly pod vetch. http://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/namoi-woolly-pod-vetch

9 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

penetration during irrigation, making the water storage low. Additionally, waterlogging is common in sodic soil, since swelling and dispersion closes off pores, reducing the internal drainage of the soil. Sodicity of the surface soil is likely to cause dispersion of surface aggregates, resulting in surface crusts.

Soils with an exchangeable sodium percentage (ESP) ≥6 are classified as sodic. Poor drainage, surface crusting, hardsetting (Photo 1) and poor trafficability or workability are common when the soil has a large proportion of sodium ions (Na+), leading to reduced crop yield.

A surface crust is typically less than 10 mm thick and when dry can normally be lifted off the loose soil below. Crusting forces the seedling to exert more energy to break through to the surface, thus weakening it. A surface crust can also form a barrier reducing water infiltration.

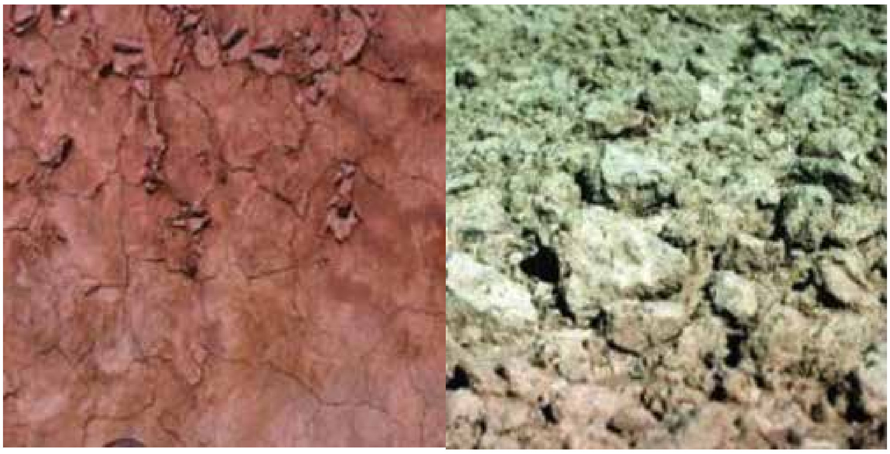

Photo 1: *Soil crusting (left) and cloddy seedbed (right) associated with high concentrations of exchangeable sodium; i.e. sodic soil.*

Source: Soilquality.org

Field research in Victoria/South Australia indicates that soil salinity and sodicity can substantially reduce crop yields. [10] Vetch yield declines when soil ECe is less than 3.0 dS/m. Yield declines at the rate of 11% for each unit increase in ECe. This is because vetch has poor root penetration into sodic soils. [11]

Crop growth is affected by salinity and sodicity in two ways: firstly, the osmotic potential effect and secondly specific ion toxicity. Salts lowers the osmotic potential (i.e. makes it more negative) or increases osmotic pressure leading to yield losses as plants cannot extract water from soils when soil solution has lower osmotic potential than the plant cell. Grain productivity decreases as electrical conductivity (EC) and ESP of the soil increases.

Sodic soils are prone to poor soil structure, particularly if the natural equilibrium between salinity and sodicity are out of balance. High salinity helps to counteract the effects of sodicity, but as described above, can cause yield issues. Both acidic–sodic and alkaline–sodic soils occur within the Northern grains zone, often within the one soil profile. Sodic soils often disperse more after mechanical disturbance (e.g. compaction) and erosion. Gypsum application to these soils improves the soil structure facilitating leaching of salts, even under dry land conditions. Correcting cation imbalances requires providing a source of the 'good' cations, Ca2+ and/or Mg2+, which might come from gypsum, lime, dolomite applications. The choice will depend on considerations such as cost, the existing cation balance in the soil and the speed at which a change is required. The application of gypsum will generally give quicker results as it has a relatively high solubility, whereas agricultural lime has a

10 Agriculture Victoria (2009) Chapter 4: Salinity and Sodicity. Subsoils Manual. http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil_pdf/$FILE/BCG_subsoils_09_ch04.pdf

11 CRDC. Comparative advantages/disadvantages of rotation crops with cotton. http://www.cottoninfo.com.au/sites/default/files/tools/CottonRotation/Rotation_chart_Page_1small.pdf

very low solubility and therefore takes longer to observe results. It is also dependant on the pH of the soil.

The use of decision process models such as Gypsy© can be used as a guide when deciding on the cost of gypsum applications. [12]

Plant available water capacity

A key determinant of potential yield in dryland agriculture is the amount of water available to the crop, either from rainfall or stored soil water. In the Northern region, the contribution of stored soil water to crop productivity for both winter and summer cropping has long been recognized. The amount of stored soil water influences decisions to crop or wait (for the next opportunity or long fallow), to sow earlier or later (and associated variety choice) and the input level of resources such as nitrogen fertiliser.

The amount of stored soil water available to a crop - Plant Available Water (PAW) – is affected by pre-season and in-season rainfall, infiltration, evaporation and transpiration. It also strongly depends on a soil's Plant Available Water Capacity (PAWC), which is the total amount of water a soil can store and release to different crops. The PAWC, or 'bucket size', depends on the soil's physical and chemical characteristics as well as the crop being grown.

Information regarding the PAW at a point in time, particularly at planting, can be useful in a range of crop management decisions. Estimating PAW, whether through use of a soil water monitoring device or a push probe, requires knowledge of the PAWC and/or the Crop Lower Limit (CLL).

A wide variety of soils in the Northern region have been characterised for PAWC and the characterisations are publicly available in the APSoil database, which can be viewed in Google Earth and in the 'SoilMapp' application for iPad.

Factors that influence PAWC

An important determinant of the PAWC is the soil's texture. The particle size distribution of sand, silt and clay determines how much water and how tightly it is held. Clay particles are small (< 2 microns in size), but collectively have a larger surface area than sand particles occupying the same volume. This is important because water is held on the surface of soil particles which results in clay soils having the ability to hold more water than a sand. Because the spaces between the soil particles tend to be smaller in clays than in sands, plant roots have more difficulty accessing the space and the more tightly held water. This affects the amount of water a soil can hold against drainage (DUL) as well as how much of the water can be extracted by the crop (CLL).

The effect of texture on PAWC can be seen by comparing some of the APSoil characterisations from the Northern region. The soil's structure and its chemistry and mineralogy affect PAWC as well. For example, subsoil sodicity may impede internal drainage and subsoil constraints such as salinity, sodicity, toxicity from aluminium or boron and extremely high density subsoil may limit root exploration, sometimes reducing the PAWC bucket significantly.

The CLL may differ for different crops due to differences in root density, root depth, crop demand and duration of crop growth. Some APSoil characterisations only determined the CLL for a single crop. [13]

MORE INFORMATION

Methods and tools to characterise soils for plant available water capacity (Coonabarabran)

12 M Crawford (2015) GRDC Update Papers: Profit suckers – understanding salinity, sodicity and deep drainage. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Profit-suckers-understanding-salinity-sodicity-and-deep-drainage

13 K Verburg, B Cocks, T Webster, J Whish (2016) GRDC Update Papers: Methods and tools to characterise soils for plant available water capacity (Coonabarabran). https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Methods-and-tools-to-characterise-soils-for-plant-available-water-capacity-Coonabarabran

Testing for sodicity

The first step in determining whether a soil needs treatment for sodicity is to determine how sodic it is using a dispersion test. If this test gives a dispersion score of 6 to 16, then the soil may be gypsum responsive. In this situation do a soil test to calculate the ESP.

Ensure to sample both surface and subsurface soil layers. There is increasing evidence of the value of assessing soil-based physicochemical constraints to production, including sodicity, salinity and acidity/aluminium, from both the surface and subsoil layers. Soil sampling to greater depth (0 to 60 cm) is considered important for testing sodicity.

Applying gypsum

Gypsum contains calcium sulfate. Calcium sulfate is a salt, but unlike sodium chloride (the main component of salt in saline water tables) it is not toxic to plants. Gypsum will help to reduce swelling and dispersion of the soil through two mechanisms. These are:

1. Gypsum slightly increases the salinity of the soil solution, and hence reduces swelling. The same effect can be seen when using saline bore water, but this often contains high levels of sodium and chlorine that are toxic to plants. Gypsum will slightly increase salinity without any detrimental effect on plants.
2. Calcium from the gypsum will swap with the sodium that is held on the clay surfaces, which is then leached down the profile away from the plant roots. This reduces the sodicity of the soil and is called cation exchange.

Gypsum can provide better soil tilth, and can reduce crusting in sodic surface soils, hence improving establishment. If using gypsum where the surface soil is sodic, time the application so that rain or irrigation does not leach the gypsum from the surface soil by sowing time.

In soils with moderate surface sodicity, applying gypsum at 2.5–5.0 t/ha has been found to significantly improve wheat grain yield in Queensland. [14] Be wary that gypsum application may reduce nodulation in lupin crops. This was found in trials in Western Australia, where the increased salt levels in the soil due to gypsum application was found to impair lupin nodulation. [15]

Cultivation practices on sodic soils should be aimed at preserving soil organic matter in the surface soil. This is usually achieved by less aggressive, reduced tillage. Non-inversion tillage is useful for leaving the more sodic subsoil at depth. In many soils of the Murray and Murrumbidgee Valleys (especially red brown earths), the topsoil is non-sodic and of reasonable depth (10 to 40 cm). However, these soils will often have sodic subsoils. Gypsum applications to these soils will have little effect on the topsoil but will increase the structure, aeration and permeability of the subsoils. This is likely to increase water storage and reduce waterlogging.

The depth of the non-sodic topsoil is an important consideration in the likely response of a sodic subsoil to gypsum improvement. Since a non-sodic topsoil is a better environment for plant growth anyway than a sodic topsoil, responses to gypsum will be low or unlikely when there is good depth of topsoil—the existing soil structure will allow optimum plant growth.

As a rough guide, if the non-sodic topsoil is greater than 15 to 20 cm deep, then a gypsum response may be unlikely. Remember, it may take a few months before gypsum leaches into the subsoil and begins to take effect.

MORE INFORMATION

Lime, gypsum and dolomite for acid soils

14 Soilquality.org (2017) Seedbed soil structure decline, Queensland. Soilquality.org, http://www.soilquality.org.au/factsheets/seedbed-soil-structure-decline-queensland

15 S Loss, L Moreschi (2004) Lime, gypsum and dolomite for acid soils. Liebe Group. Online farm trials. http://www.farmtrials.com.au/trial/10345?search_num=4

Deep ripping

This can be used to break up compacted and poorly structured soils and to help generate structure and porosity. However, the benefits can be very short-lived. Sometimes deep ripping makes the soil worse because worked (tilled) soil disperses more readily. Ripping can bring up large clods of dispersive soil and bring toxic elements such as boron and salt to the surface. Consequently, only undertake deep ripping after careful consideration. If in doubt, first carry out deep ripping on a small test strip. After ripping apply gypsum or lime (in acid soils), preferably with additional organic matter, to help stabilise the deep ripped soil. A tramline (controlled traffic) farming system will help prevent re-compaction of the loosened soil. [16]

Lime application to sodic soils

Lime (calcium carbonate), like gypsum, is a compound containing calcium. Therefore, it can contribute to reducing the effects of sodicity. However, lime is relatively insoluble at a soil pH ($CaCl_2$) above 5. In most soils of the Murray and Murrumbidgee Valleys the pH ($CaCl_2$) is above 5, so lime is of little benefit. If the pH is below 5, lime will help to reduce both acidity and sodicity problems. A mixture of lime and gypsum may be a good option on sodic soils with a pH ($CaCl_2$) in the 5 to 6.5 range, to provide a more long-lasting effect than gypsum only. Again, soil tests and test strips are strongly recommended.

MORE INFORMATION

Sodic soil management

Sodic soils a management labyrinth

Cultivating sodic soils

dispersive and sodic soils are more prone to structural degradation than non-sodic soils. For this reason, they must be cultivated minimally and carefully. Excessive cultivation of these soils will cause major soil structure problems. In this may be evident as crusting, hardsetting and poor water penetration. [17]

1.1.4 Soil salinity

Key points:

- Soil salinity varies across the landscape and within paddocks.
- The severity varies over time, in response to both climate and land management.
- Soil salinity can be managed by farming actions.
- Vetch is sensitive to long periods (over 7 days) of saline conditions.

What is soil salinity?

A saline soil is one that contains sufficient soluble salts (most commonly sodium chloride) that the growth of most plants is retarded, with damage occurring sooner in plants more sensitive to salt and much later in salt-tolerant plants such as saltbush. Salinity reduces a plant's ability to extract water from the soil, and specific ions in the salts can cause toxicity. A salinity outbreak is where symptoms of salinity are present.

Soils become saline via interaction with groundwater. If groundwater rises to within two metres of the soil surface, capillary action can bring water to the surface. When this happens, salts dissolved in the water are brought into the root zone, and when the water evaporates at the soil surface, concentrated salts are left behind.

Salinity affects crop yield and growth in dryland regions mainly by reducing Water Use Efficiency of crops through osmotic effect. Toxic effects of individual ions such as sodium can also cause yield reduction. When the osmotic pressure of the soil solution is less than (<) 700 kilopascals (kPa), there is a low rate of reduction in yield irrespective of the type of ions (salt). At these lower osmotic pressures the specific ion effect, particularly of sodium, is significant.
For osmotic pressure greater than (>) 700 kPa the rate of crop yield reduction is

16 T Overheu (2017) Management of dispersive (sodic) soils experiencing waterlogging. DAFWA. https://www.agric.wa.gov.au/water-erosion/management-dispersive-sodic-soils-experiencing-waterlogging

17 NSW DPI (2009) Chapter D5. Sodic soil management. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/127278/Sodic-soil-management.pdf

severe. When the osmotic pressure is above 1,000 kPa, the crop yield is reduced by >50% and 80–95% of available soil water is not taken up by plants. [18]

Measuring salinity

Soil salinity varies across paddocks and farms, and vertically within the soil profile. Soil may be saline at depth but not in the topsoil. This situation indicates that there may be a future problem in the topsoil.

Samples can be taken to assess salinity by measuring the electrical conductivity (EC) of soil and water. EC is usually measured in dS/m). Distilled water has an EC of 0 dS/m, sea water has an EC of 35–55 dS/m, and the desirable limit for human consumption is 0.8 dS/m. Measurements may be taken instead of the electrical conductivity of a soil extract (ECe), of a water sample (ECw) and of irrigation water (ECiw) or drainage water (ECdw).

Dryland salinity

Dryland salinity occurs when naturally occurring salts in rocks and soil are mobilised and redistributed by water, e.g. by surface run-off after rain, the recharge of groundwater, subsurface lateral flows of groundwater, or groundwater discharge. It occurs throughout NSW (Photo 2). [19] Saline outbreaks in upland areas of the NSW Murray–Darling Basin cover around 62,000 hectares, but individual areas are usually less than 10 hectares. Most salt scalds occur in the 600–700 mm rainfall zone.

Photo 2: *Scalding by salt.*

Photo: Graham Johnson, NSW Government

Irrigation salinity

Irrigation salinity in NSW occurs mainly in southern NSW in the Murray and Murrumbidgee irrigation areas.

Areas of land affected by irrigation salinity have dropped sharply in the last 10 years (from 2015), from 14,000 hectares to less than 500 hectares in the Murray Valley. The mechanisms for this change are not completely understood, but are possibly due to a combination of reduced winter rainfall and better farm management and infrastructure.

Managing groundwater levels

Salinity management aims to maintain groundwater levels at least two metres below the soil surface, mainly by maximising the water plants use to reduce groundwater recharge. Useful techniques include:

- Monitoring groundwater levels.

18 P Rengasamy (2006) GRDC Final Reports: UA00023 – Improving farming systems for the management of transient salinity and risk assessment in relation to seasonal changes in southern Australia. http://finalreports.grdc.com.au/UA00023

19 S Alt (2017) Salinity, New South Wales. Soilquality.org, http://soilquality.org.au/factsheets/salinity-nsw

MORE INFORMATION

Improving farming systems for the management of transient salinity and risk assessment in relation to seasonal changes in southern Australia

- In low lying, non-production areas, growing species tolerant of salt and waterlogging.
- Growing perennial pastures, as they can use twice as much water as annual pastures.
- Avoiding long fallows when the profile is greater than 75% of field capacity.
- Appropriate crop selection and crop rotations.
- Efficient irrigation management.

Troubleshooting

Recognising and acting on salinity problems early is the best solution, as salinity can be a more difficult and expensive issue to correct once it is well advanced. **Dryland salinity** outbreaks can be managed by excluding grazing on saline areas and sowing saline tolerant species. **Irrigation salinity** can be managed by improving irrigation management, specifically application efficiency. Specific management of salt-affected areas could include having hill and bed shapes that minimise salt accumulation around seedlings, and pumping and recycling groundwater (although this requires advice from a hydrology consultant). [20]

1.1.5 Soil pH

Vetch grows best on soils with neutral pH. Lime pelleting at sowing is recommended when planting into acid soils below pH 5.5. [21]

Acidic soil

Acidic soils are an impediment to agricultural production. More than half of the intensively used agricultural land in NSW is affected by soil acidity.

Acidity reduces the survival of Rhizobia and the effective infection of legume roots. When rhizobia are affected by soil acidity it shows as poor nodulation and results in reduced nitrogen fixation. Often Rhizobium bacteria are more sensitive to soil acidity than the host plant. Lime pelleting of inoculated legume seed is used to protect the inoculum against drying out and contact with fertiliser. Sowing into bands of limesuper also creates an environment suitable for survival of the inoculum in an acidic soil.

Management

If only the top 10 cm of the soil profile is acidic it can be readily corrected by applying and incorporating finely ground limestone. However, if acidification of the soil continues and the surface pHCa drops below 5.0 the acidity will leach into the subsurface soil (Figure 3). The further the acidity has moved down the profile the greater the effect on plant growth and the more difficult it is to correct. This is called subsurface soil acidity and is a long-term degradation of the soil.

20 S Alt (2017) Salinity, New South Wales. Soilquality.org, http://soilquality.org.au/factsheets/salinity-nsw

21 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

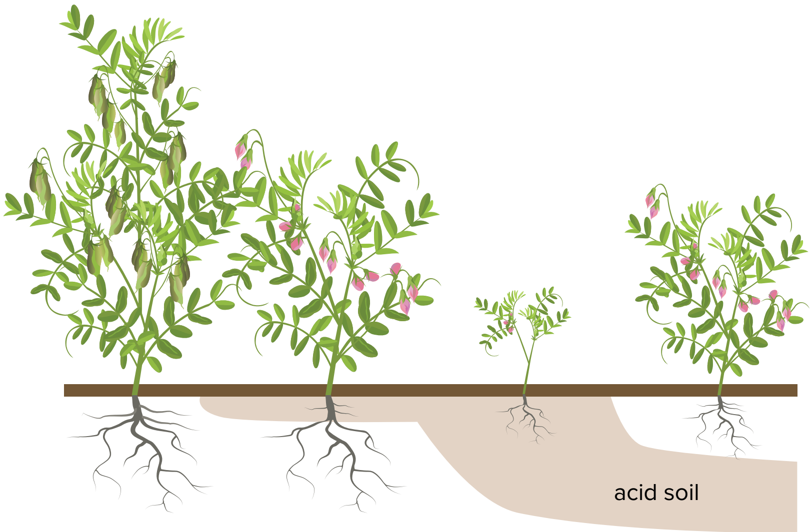

Figure 1: *The development of subsoil acidity and the implications for acid sensitive plants. a) No acidic soil problemsb) Acidification starts at the surface restricting surface root development. c) Acidity is leached to depth when the pHCa of the surface soil drops below 5.0 and all root growth is restricted. d) Subsurface soil acidity is permanent as surface applied lime only corrects acidity in the surface soil.*

Source: NSW DPI

There are a number of agronomic practices to reduce soil acidification including; growing acid tolerant crops, reducing leaching of nitrate nitrogen, using less acidifying fertilisers and preventing erosion of topsoil. However, the most direct way of improving soil acidity is through liming.

Application of finely crushed limestone, or other liming material, is the only practical way to neutralise soil acidity. Limestone is most effective if sufficient is applied to raise the pHCa to 5.5 and it is well incorporated into the soil. Where acidity occurs deeper than the plough layer, the limestone will only neutralise subsurface soil acidity if the pHCa of the surface soil is maintained above 5.5. The liming materials most commonly used are agricultural limestone and dolomite, but other materials are available.

Recommended liming rates based on a standard soil test are given in Table 3. Apply limestone before the most acid sensitive crop or pasture in a rotation as it gives the best economic return. If the limestone will not be effectively incorporated due to reduced tillage then apply the limestone a year before the most sensitive crop and apply it at a slightly heavier rate. These two actions will enhance lime movement into the top soil. The time of the year when lime is applied is not important. Limestone begins to become effective as soon as the soil is moist and reaches its major impact after 12–18 months.

Table 3: *Limestone required (fine and NV>95) to lift the pH of the top 10 cm of soil to 5.2. Colour codes group limestone rates to the nearest 0.5 t/ha.*

Soil test ECEC (meq/100 g)	Lime required (t/ha) to lift the pH of the top 10 cm:			
	from 4.0 to 5.2	from 4.3 to 5.2	from 4.7 to 5.2	from 5.2 to 5.5
1	1.6	0.8*	0.3*	0.2*
2	2.4	1.2	0.5*	0.4*
3	3.5	1.7	0.7	0.5*
4	3.9	2.1	0.9	0.6
5	4.7	2.5	1.1	0.7
6	5.5	3.0	1.2	0.8
7	6.3	3.3	1.4	1.0
8	7.1	3.8	1.6	1.1
9	7.9	4.2	1.8	1.2
10	8.7	4.6	1.9	1.3
15	12.5	6.7	2.8	1.9

*It is recognised that low rates of lime are impractical to apply, but over-liming can cause nutrient imbalances, particularly in these light soils.

KEY: Limestone rates per hectare

0.5 t/ha	1.0 t/ha	1.5 t/ha	2.0 t/ha	2.5 t/ha	3 to 4 t/ha	Split applications are advised

Source: NSW DPI

Because limestone moves very slowly down through the soil, incorporation should be to the depth of the acidity problem (or as deep as practicable) for the most effective and speedy response. [22]

Testing soil

Soil pH is a measure of the concentration of hydrogen (H +) ions in the soil solution, measured on a logarithmic scale from 1 to 14, with 7 being neutral (Figure 2). The lower the pH, the greater the acidity. A soil with a pH of 4 has 10 times more acid than a soil with a pH of 5, and 100 times more acid than a soil with a pH of 6.

MORE INFORMATION

Soil acidity and liming

22 B Upjohn, G Fenton, M Conyers. (2005). Agfacts: Soil acidity and liming. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/167209/soil-acidity-liming.pdf

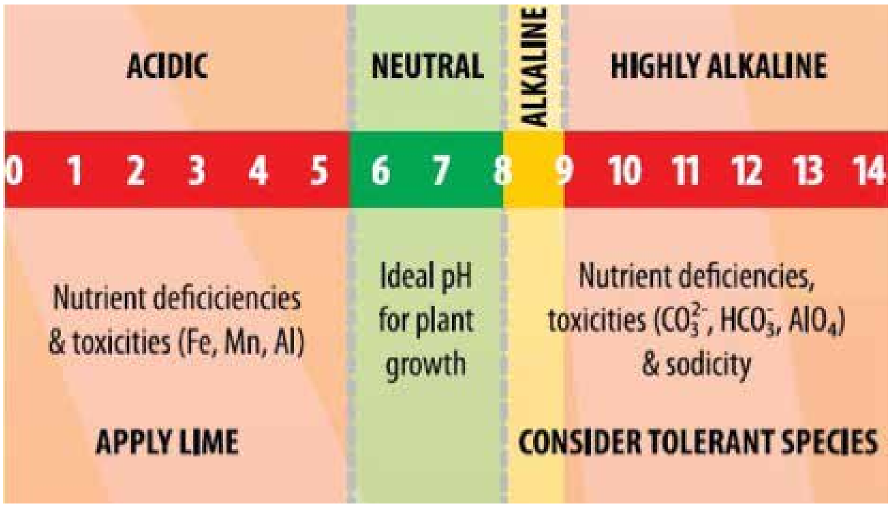

Figure 2: *Classification of soils on the basis of pH (1:5 soil:water), the implications for plant growth and some management options.*

Source: Soilquality.org

The standard measurement of soil pH uses a mixture of one part soil to five parts 0.01 M $CaCl_2$ (calcium chloride). Measured in water, pH can read 0.6–1.2 pH units higher than in calcium chloride, and soils with low total salts show large seasonal variation if pH is measured in water. Field soil pH kits give results similar to water measurements and complement periodic laboratory testing.

The best time to soil test is in autumn, two to ten days after good rain. Samples should not be taken from; overly wet or dry soils, at times of extreme high or low temperatures, within a few weeks of fertiliser applications, or within months of lime application. Sampling sites should take account of paddock variability and be recorded using GPS (Photo 3). Samples at the soil surface and subsurface will determine the soil pH profile and detect subsurface acidity. Sampling should be repeated at the same locations, same time of year and under similar conditions at least every three to four years to detect changes and allow adjustment of management practices. [23]

23 S Alt, P Gazey. (2013). Soil acidity – NSW. Soilquality.org. http://www.soilquality.org.au/factsheets/soil-acidity-new-south-wales

Photo 3: *Soil cores need to accurately reflect the main soil type in the paddock being tested.*

Photo: N Baxter, Source: GRDC

1.2 Paddock rotation and history

Northern region grain growers have embraced crop rotations for the benefits they offer for producers operating within an increasingly challenging cropping environment. More and more growers are understanding there are no quick fixes for many of the region's grain growing challenges and are turning to a farming system approach hinging on crop sequencing, herbicide rotations, integrated weed and pest management (IWM and IPM) and practices such as minimum tillage that promote soil health.

To limit the risk of disease in vetch and other pulses in the cropping sequence, vetch should be limited to no more than once in every four years in a particular paddock. [24]

Vetch is susceptible to ascochyta blight, botrytis grey mould and rusts, and it is not recommended to sow vetch into paddocks where inoculum may be present.

Sow vetch into paddocks where Group E inoculant has been present before, otherwise it is highly recommended to inoculate vetch with Rhizobia.

Vetch is often grown for its benefits to following cereal rotations.

1.3 Benefits of vetch as a rotation crop

Vetch is valued for its benefits to subsequent cereal and oil seed crops in the rotation, these benefits are usually greater than from other pulses particularly in lower rainfall areas. Vetch has been adopted by Australian farmers as a legume rotation crop where drought is the major environmental stress. Its substantial root system and its ability to flower quickly and set seed in a dry spring give it good drought tolerance. Vetch is better adapted to these regions than field peas, chickpeas, lentils, faba beans or lupins. [25]

On sandy soils vetches provide better soil protection than peas and provide better stubble retention in the soil.

24 R Matic (2010) Vetch summary 2010. SARDI. Online Farm Trials. http://www.farmtrials.com.au/trial/14055

25 R Matic (2015) GRDC Final Reports: DAS00013 – Vetch variety improvement for Australian field crop farming systems. https://grdc.com.au/research/reports/report?id=268

Vetches have the ability to offer substantial improvements in soil fertility, structure and organic matter. Vetch can increase soil nitrogen, decrease weeds and make direct drilling easier. Savings on fertiliser and herbicides for the following grain crop are two major incentives for using vetch. In addition to viable grain and forage production from vetch, cereal crop yields following a vetch crop are usually at least 30% to 50% higher than those derived from continuous cropping with cereals (Photo 4).

Vetch can provide alternative options to pulses for grain and potentially some management of frost risk. [26]

Vetch has become an increasingly important crop for the less productive areas in southern Australian cropping regions. Vetch is grown with low inputs despite the recognised nutritional and agronomic benefits it provides.

Photo 4: *The effect of rotation is clear – the canola/wheat/wheat rotation (left) had 31 kilograms of nitrogen per hectare applied, while the vetch/canola/wheat rotation (right) had 9 kg of N/ha applied.*

Source: GRDC

1.3.1 Nitrogen fixation

Vetch is a versatile nitrogen fixing legume and green manure crop offering significant benefits to graingrowers.

The amount of nitrogen returned to the soil is between 42 and 67 kilograms a hectare after grain production, up to 97 kg/ha after grazing or cutting for hay and 154 kg/ha after green manuring. [27]

For more information, see Section 5: Nutrition and fertiliser section 5.1 Crop removal rates.

Trials in the Riverine plains in 2012 exploring the amount of nitrogen produced by break crops found that vetch produced the most total plant fixed nitrogen (141 kg N/ha) followed by the arrowleaf clover (138 kg N/ha), faba beans (129 kg N/ha) and sub-clover (118 kg N/ha). These results were significantly higher than field peas (86 kg N/ha) and chickpeas 50 kg N/ha) (Table 3).

The clover and chickpeas treatments did not appear to fix nitrogen as efficiently as the other legumes with only 12–13 kg fixed N/t shoot DM compared with the faba beans and field peas fixing 15–16 kg fixed nitrogen per tonne of shoot DM or the 19 kg fixed nitrogen per tonne of shoot DM for the vetch (Table 4). [28]

26 L McMurray (2013) GRDC Update Papers: Best bet options and practices for pulses in the Mallee. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/08/best-bet-options-and-practices-for-pulses-in-the-mallee

27 K Penfold (2006) Vetch interest puts pressure on supply. Groundcover GRDC. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-60/vetch-interest-puts-pressure-on-supply

28 A Glover, I Trevathan, L Watson, M Peoples, T Swan (2012) Break crops in cropping systems: impacts on income, nitrogen and weeds. Riverine Plains, Online farm trials. http://www.farmtrials.com.au/trial/16519

MORE INFORMATION

Break crops in cropping systems: impacts on income, nitrogen and weeds

Crop sequence trial demonstrates break crop benefits

Grain and graze: We grow vetch because we want our children to be farmers

Break crops in retained stubble systems

Table 4: *Nitrogen fixation results for legumes sampled at peak biomass.*

Treatment	Mean shoot DM (t/ha)	Shoot N (kg N/ha)	% N fixed	Shoot N fixed (kg N/ha)	Shoot N fixed (kg N/t DM)	^Total N fixed (kg N/ha)
Vetch	5.1	120	79	95	19	141
Arrowleaf clover	6.1	100	81	80	13	138
Faba beans	5.3	105	82	85	16	129
Sub-clover	5.8	99	69	69	12	118
Field peas	4	93	64	58	15	86
Chickpeas	2	37	65	24	12	50
Lupins*	0.6	20	82	16	25	21
P-value	(<0.05)	<.001	<.001 NS	<.001	<.001	<.001
LSD	1.21	22	15	17	4	27

* Lupins were severely affected by bird damage and were not harvested. ^ Total nitrogen fixed (kg N/ha) estimates for the amount of nitrogen fixed from both the shoots and roots. Determined using root factors obtained from previous N fixation studies.

Source: Riverine plains, Online Farm Trials

MORE INFORMATION

Break crops in cropping systems: impacts on income, nitrogen and weeds

Trials in the Mallee found that vetch biomass of 3–5 t/ha can fix a total of 200–300 kg N/ha. This level of nitrogen can cause the following wheat crop to hay off if a dry summer and growing season follow the vetch production year. An early termination of vetch (at 2 t/ha biomass) can be lower risk if the seasonal outlook is dry. [29]

For more information on when to terminate vetch, see Section 11: Crop desiccation and spray out.

Trials have shown that growing vetch as either a green manure crop or for grain production before a wheat crop is one of the most cost-effective methods of achieving high yielding, high-quality wheat. An SA grower group, the Lameroo Premium Wheat Marketing Association, conducted wheat protein trials in the Southern Mallee to assess the value of vetch in a rotation and found it one of the most cost-effective methods of achieving high yielding, quality grain. In the following wheat crop, grain yield increased by 32% and protein by 1.8% when compared with cereal on cereal. [30]

1.3.2 Disease, weed and pest reduction

Vetch can reduce disease and insect risk for the following crop. [31] Vetch in cereal rotations allows growers to control diseases such as take-all and cereal cyst nematode (CCN). Disease-resistant varieties can be successfully grown without fungicide use. [32]

Vetch can also open up weed control options in a cropping sequence. They have useful tolerance to the triazine group of herbicides (e.g. atrazine). This enables vetch to be double-cropped after sorghum or maize provided that excessively high rates of atrazine have not been used in the preceding summer cereal. Any likelihood of crop damage to the vetch will be further minimised by only planting in situations where there is a reasonable profile of sub-soil moisture at planting (60 cm wet soil). [33]

29 D Ferrier, A Frischke (2016) Break crops in retained stubble systems in the Wimmera and Mallee. Birchip Cropping Group. https://thestubbleproject.wordpress.com/2016/05/31/wimmera-and-mallee-breack-crops/

30 K Penfold (2006) Vetch interest puts pressure on supply. Groundcover GRDC. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-60/vetch-interest-puts-pressure-on-supply

31 R Matic, S McColl (2013) Which vetch in my farming system? Online farm trials. http://www.farmtrials.com.au/trial/16634

32 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

33 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

Soft seeded species are suitable for use in all crop rotations, without the risk of voluntary plants creating a problem in following crops; e.g. new common vetch varieties (Morava⁽ᴅ and Rasina⁽ᴅ) are soft seeded varieties and have no potential to be a weed in subsequent crops. [34]

1.3.3 Brown manuring

Brown manure cropping involves growing a grain legume crop with minimal fertiliser and herbicide inputs to achieve maximum dry-matter production before the major weed species have set viable seed.

The grain legume crop is sprayed with a knockdown herbicide before seed-set to kill the crop and weeds, ideally no later than the start of the crop's pod development to also conserve soil moisture.

A second knockdown herbicide is generally applied to achieve a 'double knock'. This is different to green manure where the crop and weeds are cultivated.

Brown manuring with legumes should be considered, especially by growers in southern New South Wales, as diminishing growing-season rainfall is putting downward pressure on yields. To counter this, most growers are increasing the quantity – and cost – of inputs, particularly herbicides and nitrogen. This adds even more to production and financial risks. [35]

Trials in southern NSW exploring rotation benefits found that grain yield increased significantly for wheat crops following a break crop (vetch, field pea, and pasture) when brown manured. There was no difference in grain yield when vetch was brown manured or cut for hay. For the hay cut treatment, wheat following vetch produced more grain than that following pasture. Cutting for hay significantly improved financial return for the rotation including vetch ($482/year) or pasture ($453/year) as a break crop compared with the brown manure option, which is higher than the continuous-wheat option with N fertiliser applied. Due to the loss of a year's income when break crops were brown manured, the gross margin was lower than grain harvested. [36]

Another trial in southern NSW from 2012–2014 found that a vetch rotation could help to increase wheat protein. There was more protein (about 0.5%) in the wheat following pulse crops that had been brown manured (12.6%) instead of harvested for grain (12.0%). There were also differences between species, with most wheat grain protein following Morava⁽ᴅ vetch and Percy field pea, and the least protein percentage following the lupin crops. This may reflect the biomass of the preceding legumes. [37]

MORE INFORMATION

Brown manure legumes lower total crop risk

Increasing on-farm adoption of broadleaf species in crop sequences to improve grain production and profitability

Residual effects of a pulse crop phase in the farming system

1.3.4 Green manuring

Green manuring can increase both wheat yields and grain protein.

The technique involves growing as much green matter as possible, usually vetch, and either ploughing it in or spraying it with a herbicide during the spring in the year before wheat is sown.

The main differences between green manuring and traditional long fallowing are: that the legume is sown and managed to produce maximum bulk; that grasses are sprayed out to stop any build-up of root disease pathogens; and that green manuring is done relatively late in the season when the legume was at the late flowering stage.

34 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

35 GRDC. (2015) Groundcover Issue 116: Brown maure legumes lower total crop risk. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-116-may-june-2015/brown-manure-legumes-lower-total-crop-risk

36 G Li, R Lowrie, G Poile, A Lowrie (2015) Increasing on-farm adoption of broadleaf species in crops sequences to improve grain production and profitability. NSW DPI – Southern NSW research results 2015. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/660496/Southern-NSW-research-results-2015.pdf

37 E Armstrong, L Gaynor, G O'Connor, S Ellis, N Coombes (2014) Residual effects of a pulse crop phase in the farming system. NSW DPI – Southern cropping region trial results 2014. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/561344/Southern-cropping-region-trial-results-2014.pdf

In subtropics in northern New South Wales and southern Queensland, vetch is used mainly as a green manure in cotton production, orchards and vineyards (Photo 5). [38]

Photo 5: *Vetch being slashed in late winter prior to incorporation into the soil.*

Source: Cotton Catchment Communities CRC

Vetch trials in southern Australia have shown that green manuring by ploughing increased yields by 0.64 t/ha and protein by 1.2%, while the figures for spraying were 0.34 t/ha and 0.9% protein. However, in other trials, wheat yields after spraying matched those after ploughing, especially where vetch rotted quickly because of follow-up rains. Spraying rather than ploughing may be preferable where soil is prone to erosion.

The researchers also compared returns from the green manuring with returns from simply letting the vetch mature and harvesting it, then sowing wheat back on the paddock. They found that harvesting both crops gave a better return. However, their calculations did not take into account benefits of green manuring in reducing herbicide resistance or increasing soil fertility.

The researchers recommended that in intensive cropping rotations, green manuring (e.g. with vetch) should take place every five to six years. [39]

Soil structure

Vetch has been part of trials exploring the effect of legumes on soil structure. Soil structural differences are measured with a cone penetrometer which determines the force needed to push a metal probe slowly into the soil to 600 mm depth. The results (Figure 3) indicate that the instrument penetrated the soil more easily in the vetch systems compared with the non-legume systems. This effect was more evident in the subsoil. This phenomenon has been observed in each year of the experiment. Soils that offer less resistance to root growth allows the crop to explore a larger volume of soil, thereby enabling the crop to take up more nutrients and to access more soil water. [40]

38 R Matic, S Nagel, G Kirby (2008) Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

39 A Mayfield. Groundcover Issue 12: Green boost for wheat. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-12/green-boost-for-wheat

40 I Rochester (2009) GRDC Update Papers: Using rotation crops to improve soil quality. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2009/10/using-rotation-crops-to-improve-soil-quality

MORE INFORMATION

Manuring of Pulse Crops

Using rotation crops to improve soil quality

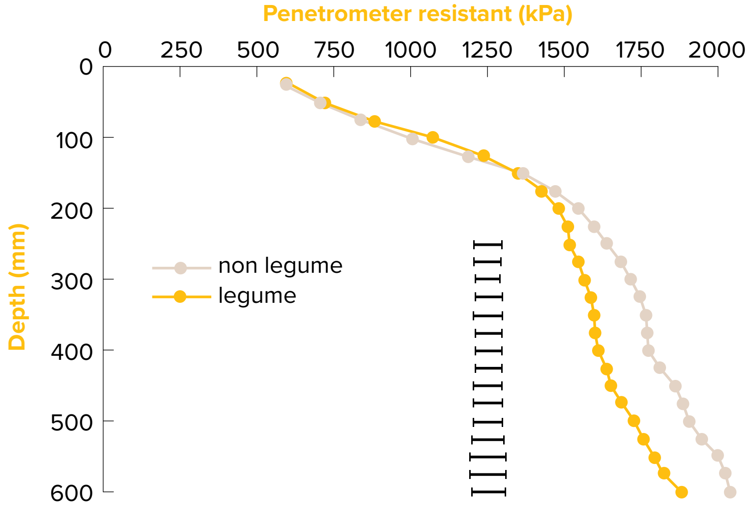

Figure 3: *Resistance to inserting the cone penetrometer in to soil was lower following a legume (vetch) crop, compared with fallow.*

Source: GRDC

1.4 Disadvantages of vetch as a rotation crop

Key points:

- Contamination of following pulse crops with vetch seed.
- Controlling weeds in vetch can be problematic. There is also risk of volunteer vetch causing problems in a cropping sequence.
- Vetch is not well-adapted to waterlogging.
- In early growth stages vetches are sensitive to redlegged earth mite, and lucerne flea, and in mid to later growth to cowpea aphids as well to Native budworm at flowering and podding stages. [41]

While cultivated vetch is still gaining popularity as a hardy pulse alternative, increasing numbers of wild vetch or tares are being viewed with alarm in some areas (Photo 6). Wild vetch has the potential to become a severe problem in the cropping systems of south eastern Australia. Once established, it is highly competitive in crops such as lupins.

Wild Vetch is an autumn-germinating annual broadleaf weed. They have a high percentage of hard seeds which may survive indefinitely and germinate if conditions are favourable. Cultivation to bury the seed and prevent germination is not effective. Seed germination trials showed vetch has the ability to germinate from a depth of 250 mm.

Vetch is classified as a Class 7 contaminant in ASW standard wheat by the Australian Wheat Board. This means that no more than one vetch seed per 0.5 L grain sample is allowed. Contamination above this level would result in the grain being rejected.

41 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

Photo 6: *Vetch tares in a paddock.*

Photo: Peter Teasdale

In early trials, simazine alone, applied post-sowing, pre-emergence, was found to provide very little vetch control. Later applications of other herbicides were more effective at retarding vetch growth. Most effective was herbicide application at the 2–3 leaf growth stage, achieving reasonable control.

Cultivated varieties of vetch are easier to control as they are not as hard-seeded as their wild relatives. Germination percentages of cultivated varieties are relatively high and with the correct timing of herbicide application can be well controlled. [42]

New common vetch varieties (Morava⟮D⟯ and Rasina⟮D⟯) are soft seeded varieties and have no potential to be a weed in subsequent crops. However, older varieties like Blanchefleur and Languenoc have 5–20% hard seeds and can potentially be a weed in the following 2–3 years. In cereal crops the voluntary common vetches can be easily controlled by many broadleaf herbicides that are regularly used for controlling broadleaf weeds.

Post emergent herbicide options for broadleaf weed control are limited.

1.4.1 Disadvantages of Woolly pod vetch

Woolly pod vetch grain cannot be used for feeding any livestock. Varieties are hard seeded (10–70%) and can occur as voluntary plants/weeds in following crops for many yrs.

Initial growth is poor and requires clean land before seeding. In early growth stages it is a very poor competitor to weeds.

Woollly pod vetch cannot perform well in low/medium rainfall (<400 mm/year) areas.

This vetch species is not well adapted to waterlogging.

In early growth stages, woolly pod vetch is sensitive to lucerne flea and in mid to later growth to cowpea aphids as well as to Heliothus in flowering and podding stages.

Herbicide options for broadleaf weed control are limited. [43]

42 A Chambers in GRDC. Groundcover Issue 16: All vetches aren't equal. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-16/all-vetches-arent-equal

43 R Matic, S Nagel, G Kirby (2008) Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

1.5 Fallow weed control

Fallows are an inherent part of farming in lower rainfall areas. The main function of a fallow is to conserve moisture and nutrients for the following crop. Fallows can also reduce the carryover of disease and the number of weeds into the next crop. The benefits of a fallow are only attained when the weeds in the fallow are controlled (Photo 7). Fallows can be used as an Integrated Weed Management (IWM) tool to target cropping weeds such as annual grasses. [44]

Photo 7: *Clean summer fallows (left) prevent soil moisture being lost to weed growth (right).*

Photo: B Collis, Source: GRDC and DAFWA

Vetch should be sown into a clean seedbed, with weeds controlled prior to planting with cultivation and/or herbicides. A wide range of products are registered for controlling weeds in fallows.

1.5.1 Herbicides

Herbicides are currently the main weed control option in fallows, with glyphosate the most commonly used herbicide. There are a range of herbicides that can be used in fallow and it is important to rotate the herbicide mode of action used in fallows. Fallows managed with a single herbicide mode of action have seen a species shift towards more herbicide tolerant weeds. Herbicide mixtures with different modes of action should be used for weed control in fallow to control a broader range of weed species. Weed control in summer can be difficult as weeds grow very quickly. Weeds are most susceptible to herbicides in the two- to four-leaf stage which can occur within 14 days of germinating rain. [45]

Spray.Seed (various trade names) and Surpass + glyphosate (various trade names for both products) are registered for controlling weeds prior to planting vetch. There is a 7 – 10 day plant-back period constraint before planting vetch following a Surpass application.

For broadleaf weed control in vetch during fallow, Dicamba 500 g/L (Kamba®500) is registered for application at 0.28 L. Dicamba 700 g/kg (Cadence®) is registered for

44 A Johnson, R Thompson. Weed control for cropping pastures in central west NSW. Chapter 5: Fallows. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/154723/Weed-control-for-cropping-and-pastures-in-central-west-NSW-Part-5.pdf

45 A Johnson, R Thompson. Weed control for cropping pastures in central west NSW. Chapter 5: Fallows. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/154723/Weed-control-for-cropping-and-pastures-in-central-west-NSW-Part-5.pdf

application at 200 g. Paraquat 135 g/L + diquat 115 g/L (Spray.Seed®250) is registered for application at 1.2–3.2 L.

2,4-D amine 700 g/L (Amicide®Advance700) is registered for application at 0.515–0.745 L. [46]

For some soil-active broadleaf herbicides to be fully effective, or to avoid crop damage, application must only occur when there is sufficient soil moisture and the soil surface is level. Herbicides applied before seeding or split between pre and post-sowing can be safer than post-sowing if the soil will be left ridged (e.g. after using knife points). [47]

1.5.2 Cultivation

Weed control in fallows may require a cultivation under certain conditions (Photo 8). Considering a cultivation does not mean returning to old techniques and machinery. For example, a shallow cultivation can be used to control seedling weed growth under hot, dry and dusty conditions when herbicides are generally not as effective. A strategically targeted cultivation is also a very effective IWM tool, especially when used in rotation with herbicides to prevent a build-up of herbicide tolerant weeds. Combining herbicide use with cultivation also reduces the risk of degrading the soil structure and increasing erosion through excessive cultivation. At the end of a long fallow which has been managed with herbicides, a shallow cultivation can be useful. This cultivation, about eight weeks prior to sowing, can be used to stimulate weed emergence of dormant weed seed if large numbers of seed are known to be present. These weeds can then be controlled prior to sowing. This technique, sometimes referred to as an 'autumn tickle' is a useful technique for reducing the soil seed bank and delaying the development of herbicide resistant weed populations. [48]

Photo 8: *Lupin fits well in minimum tillage, direct drilling, no-tillage or zero-tillage farming systems provided the physical seeding process is not affected.*

Source: GRDC

46 http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/123157/Weed-control-in-winter-crops-2017.pdf

47 Pulse Australia. (2015). Lentil production: Southern region. http://pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide

48 A Johnson, R Thompson. Weed control for cropping pastures in central west NSW. Chapter 5: Fallows. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/154723/Weed-control-for-cropping-and-pastures-in-central-west-NSW-Part-5.pdf

1.5.3 Burning stubble on a short fallow

Stubble burning is a tool used for the control of disease and many weeds. Burning stubble must be weighed against the increased risks of nutrient loss and damage to the soil structure that can occur in a hot fire. High levels of ash can sometimes reduce the effectiveness of herbicides. The fire should aim to destroy weed seeds on the soil surface rather than burning fresh weed growth (Photo 9). Burning to reduce some weed seeds on the soil surface requires a hot fire, while for others a cool burn is sufficient. Seeds that are still attached to the parent plant and have not fallen to the ground are easier to burn. Research has found that while burning standing stubble temperatures were often hot enough to destroy annual ryegrass seed but not wild radish seed on the soil surface. Wild radish required 500˚C for 10 seconds; annual ryegrass only required 400˚C for the same period.

Photo 9: *A paddock of burnt stubble where a pulse crop was later sown at a property in Armatree about 100 kilometres north of Dubbo in northern New South Wales.*

Photo: S Cowley, Source: GRDC

Burning windrows (higher concentration of material) can produce temperatures that are hot enough for a sufficient period to kill wild radish seed on the soil surface. [49]

For more information, see Section 6: Weed control.

VIDEOS

WATCH: GCTV5: Managing summer fallow.

WATCH: Burning for weed and snail control.

MORE INFORMATION

Weed control for cropping and pastures, Chapter 5: Fallows.

1.6 Fallow chemical plant-back effects

Herbicide plant-back restrictions should be taken into account when spraying fallow weeds prior to sowing winter crops. Many herbicide labels place time and/or rainfall restrictions on sowing certain crops and pastures after application, due to potential seedling damage. Crops such as pulses and legume pastures are the most sensitive to herbicide residues. [50]

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.

Most herbicide residues are broken down by microbial activity in the soil. The soil microbes require warm, moist soil to survive and 'feed' on the chemical. Degradation

49 A Johnson, R Thompson. Weed control for cropping pastures in central west NSW. Chapter 5: Fallows. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/154723/Weed-control-for-cropping-and-pastures-in-central-west-NSW-Part-5.pdf

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

of chemical residue is slower when soils are dry or cold. Soil type and pH also have an influence on the rate at which chemicals degrade.

Keeping accurate records of all herbicide treatments and planning crop sequences well in advance, can reduce the chance of crop damage resulting from herbicide residues. [51]

The following plant-back periods are a guide only based on label recommendations (Table 5). The time indicated between application and safe crop rotation intervals will depend on a range of factors including rainfall (amount and intensity), soil type (pH, soil biological activity and organic carbon), soil type variability within a paddock, and temperature and herbicide rate. Some crops are more sensitive to various herbicide groups than others. Always take a conservative approach to plant-back periods, especially with sensitive or high input crops.

Table 5: *Guidelines for crop rotations – Fallow commencement/maintenance and pre-sowing seedbed weed control.*

	Specific details	Herbicide Group	Plantback period
Associate® [1]	pH 5.6–8.5 [7]	B	-
Amicide® Advance (700 g/L) [2]	<0.5 L/ha	I	7d
	0.5–0.98 L/ha	I	7d
	0.98–1.5 L/ha	I	10d
Cadence® [2]	140 g/ha	I	-
	200 g/ha	I	-
	400 g/ha	I	-
Eclipse® 100 SC	[8]	B	
LV Ester 680 (680 g/L) [2]	<0.51 L/ha	I	7d
	0.51–1.0 L/ha	I	7d
	1.0–1.6 L/ha	I	10d
Express® [3]		B	7d
Gundy 240	[9 14]	B	
Garlon™		I	-
Goal®	[10]	G	
Grazon™ Extra [4]	NNSW 0.2 L/ha	I	-
	NNSW 0.3 L/ha	I	-
	NNSW 0.4 L/ha	I	-
	NNSW 0.6 L/ha	I	-
	SNSW <0.5 L/ha	I	
Hotshot™ [4]	NNSW<750 mL/ha	I	-
	SNSW <500 mL/ha	I	-
Kamba®500 [2]	0.2 L/ha	I	-
	0.28 L/ha	I	-
	0.56 L/ha	I	-

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

	Specific details	Herbicide Group	Plantback period
Lontrel™Advanced 600 g/L [5]	NNSW <0.04 L/ha	I	-
	NNSW 0.04–0.15 L/ha	I	-
	NNSW >0.15 L/ha [11]	I	
	SNSW <0.15 L/ha	I	9mo
	SNSW <0.15–0.25 L/ha	I	12mo
	SNSW >0.25 L/ha	I	24mo
Pyresta® [2]	250–500 mL/ha	GI	7d
	900 mL/ha	GI	7d
Starane™Advanced [6]	0.225 L/ha	I	-
	0.45 L/ha	I	-
	0.9 L/ha	I	-
Sharpen®WG		G	-
Shogun®		A	-
Terrain™500 WG [13]	30 g/ha	G	0mo
	120 g/ha		1mo
	180 g/ha		1mo
	280 g/ha		2mo
Weedmaster® Argo®	[12]		-

1 For pH 8.6 and above tolerance of crops (grown through to maturity) should be determined on a small scale, in the previous season, before sowing into larger areas.

2 When applied to dry soils at least 15 mm of rain must fall prior to the commencement of the plant-back period.

3 Express® is broken down in soil, primarily by chemical hydrolysis, but to a lesser degree by microbial degradation. Breakdown is fastest in warm, wet acid soils and slower in cold alkaline soils. For summer crops (specified on the label), if minimum soil temperatures at planting depth are less than or equal to 15°C for three consecutive days, then plant-back intervals should be extended to 21 days.

4 Plant-back periods on black cracking clays. During drought conditions the plant-back period may be significantly longer.

5 Additional rainfall requirements need to be observed – see label.

6 Do not plant susceptible crops, including cotton, pigeon peas and other pulse crops, into irrigated fields with soils containing less than 25% clay content, within 12 months of treatment with Starane™ Advanced.

7 Soil pH determined by 1:5 soil:water suspension method.

8 Do not plant susceptible crops until 9 months after application of Eclipse®. Susceptible crops include canola or other brassica crops, field peas, beans, medics, Lucerne and sub-clover.

9 Minimum recropping periods are influenced by numerous factors. See label for further information.

10 Goal® herbicide at up to 75 mL/ha may be safely applied 1 day before planting wheat, barley, oats, triticale, canola, lupins, faba beans, field peas, Lucerne, clover, medics, ryegrass, phalaris and cocksfoot and 7 days minimum before planting cotton or soybeans, provided minimum tillage planting equipment is used with minimal soil disturbance.

11 Susceptible crops should not be sown for at least 2 years when Lontrel™ Advanced at more than 0.15 L/ha has been used in northern Australia.

12 Do not disturb weeds by cultivation, sowing or grazing for 6 hours of daylight following treatment of annual weeds and 7 days for perennial weeds.

13 25 mm of rain or irrigation is necessary after application and before planting winter crop species

Key: d=days mo = months

1.6.1 Conditions required for breakdown

Warm, moist soils are required to break down most herbicides through the processes of microbial activity. For the soil microbes to be most active, they need good moisture and an optimum soil temperature range of 18°C to 30°C. Extreme temperatures above or below this range can adversely affect soil microbial activity and slow herbicide breakdown. Very dry soil also reduces breakdown. To make matters worse, where the soil profile is very dry it requires a lot of rain to maintain topsoil moisture for the microbes to be active for any length of time.

Risks

In those areas that do not experience conditions which will allow breakdown of residues until just prior to sowing, it is best to avoid planting a crop that is sensitive to the residues potentially present on the paddock, and opt for a crop that will not be affected by the suspected residues. In most cases, cereals or canola would be better options as these crops are comparatively less affected by herbicide residues. If dry areas do get rain and the temperatures become milder, then they are likely to need substantial rain (more than the label requirement) to wet the sub-soil, so the topsoil can remain moist for a week or more. This allows the microbes to be active in the top-soil where most of the herbicide residues will be found. Sensitive crops include legume pastures (e.g. clovers, Lucerne, or forage legumes) and pulse crops (e.g. Vetch, lupins, lentils, fieldpeas or faba beans). [52]

For more information, see Section 6: Weed control.

MORE INFORMATION

Herbicide residues and weed control

1.7 Seedbed requirements

Preparation of a seedbed to ensure good seed soil contact is an important element in successful crop establishment. Ensure early paddock preparation to enable timely sowing.

Vetch should be sown into a clean seedbed, with weeds controlled prior to planting with cultivation and/or herbicides. A uniform and firm seed bed is required for good results.Vetches are large seeded and capable of being planted down into soil moisture. [53]

Vetch is suited to no-till, standing stubble systems.

No till crop establishment gives a huge number of benefits, the first being less soil erosion compared to tillage. Crop residues are retained on the soil surface. This reduces evaporation and protects small plants from harsh weather events.

The introduction of cover crops into no-till farming systems can provide increased soil cover, add diversity to the system and smother weeds.

1.8 Soil moisture

MORE INFORMATION

Improving soil moisture

Moisture is a key limitation on the productivity of soil.

Three main factors affect soil moisture content:

1. how well your soil can absorb water;
2. how well your soil can store moisture; and
3. how quickly the water is lost or used.

Although these factors are strongly determined by the proportions of clay, sand and silt, good soil management also plays a critical role. [54]

1.8.1 Dryland

Vetch grows well in no-till, standing stubble paddocks (Photo 10).

Sowing systems that retain stubble help to reduce evaporation losses from the soil. Retaining stubble or plant residue from previous crops also protects the soil from erosion, reduces soil moisture loss and assists in crop growth and height.

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

53 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

54 G Reid. (2004). Improving soil moisture. Agnote DPI – 494. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/166796/improve-soil-moisture.pdf

VIDEOS

WATCH: Stubble Management.

WATCH: GCTV15: Stubble height Pt. 1. and Stubble height Pt. 2.

WATCH: GCTV4: Burning for stubble retention.

MORE INFORMATION

Stubble retention in south-eastern Australia

Maintaining profitable farming systems with retained stubble across various rainfall environments

Photo 10: *Inter-row sowing vetch into cereal stubble.*

Photo: Stuart Nagel

Stubble retention

Key points:

- Retaining stubble has several advantages to soil fertility and productivity.
- Retaining stubble can decrease erosion and increase soil water content.
- Benefits of stubble retention are enhanced by reduced tillage and leguminous crop rotations.

Historically, stubble has been burnt in southern and central New South Wales because it creates easier passage for seeding equipment, enhances seedling establishment of crops, and improves control of some soil-borne diseases and herbicide resistant weeds. Heavy stubble cover can reduce evaporation by as much as 50 mm during the season. This can give significant yield improvements.

The practice of burning stubble has recently declined due to concerns about soil erosion, loss of soil organic matter and air pollution. Stubble is increasingly being retained (without burning practices) which has several advantages of soil fertility and productivity. Summer rainfall and warmer conditions promote decomposition of stubble. In northern NSW over half of the original cereal stubble may be decomposed by winter sowing time, compared to southern NSW where much more of the residue remains in place.

1.8.2 Irrigation

Even in relatively high and reliable rainfall areas, natural rainfall patterns may not match the water requirements of many commercial crops. Efficient use of irrigation water means more crop can be grown for a given volume of water, an important factor now that water supplies are becoming limited and expensive. Efficient irrigation reduces operating costs because less water has to be pumped for a given yield. 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.

Vetch is not often sown in irrigated farming operations in the Northern growing region.

MORE INFORMATION

Irrigation and drainage management plans: Part 1 and Part 2

Choosing the right soil moisture monitoring device

1.9 Yield and targets

It is important for growers to be able to predict yields and targets of their crops. Table 6 provides yield results for grain and dry matter production of common vetches varieties tested between 2011- 2014 in SA by the Australian National Vetch Breeding Program. Woolly pod vetch can perform better than common vetch for hay production in areas with > 400 mm/year rainfall, by 0.7–1.3 t. [55]

Table 6: *Grain and dry matter yield for common vetch varieties tested in trials in SA from 2011–2014.*

	(5 sites * 5 years)			
Variety	**Grain yield (t/ha)**	**% of Blanchefleur**	**Dry matter yield (t/ha)**	**% of Morava⒫**
Blanchefleur	2.15	100	4.03 (2009–13)	80
Rasina⒫	2.37	110	4.7 (2009–13)	93
Morava⒫	2.16	100	5.06	100
Volga⒫	2.75	128	5.51	109
Timok⒫	2.48	115	5.26	104
Mean yield	2.38		4.91	

Source: SARDI

Trials in the Northern region measured the relative biomass production of a range of forage crop options that could be utilised in grain crop rotations. Several experiments in southern Queensland showed Purple vetch cv. Popany to be less productive than snail medic and sulla, but at Tulloona in 2013 it produced similar biomass to the field pea and other vetch cultivars and more than sulla (Figures 4 and 5). [56]

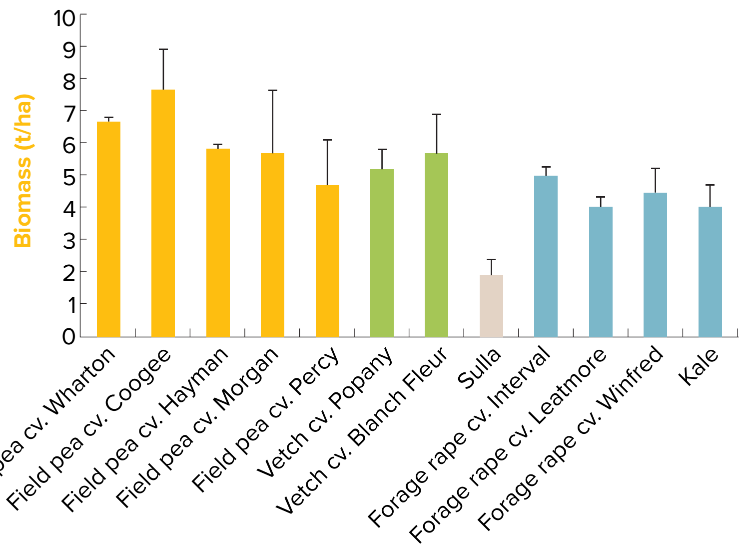

Figure 4: *Comparison of biomass production from 5 field pea cultivars (green), 2 vetch cultivars (light green), the perennial legume sulla (light green) and 4 forage brassicas at Tulloona, NSW in 2013.*

55 R Matic (2011) GRDC Final Report: New vetch varieties for grain and hay production for Australian Farmers. https://grdc.com.au/research/reports/report?id=1446

56 L Bell (2015) GRDC Update Papers: Likely fit of summer and winter forage crop options in central west farming systems. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/07/likely-fit-of-summer-and-winter-forage-crop-options-in-central-west-farming-systems

MORE INFORMATION

Likely fit of summer and winter forage crop options in central west farming systems

Yield Prophet®

Ground truthing Yield Prophet® in the southern NSW landscape

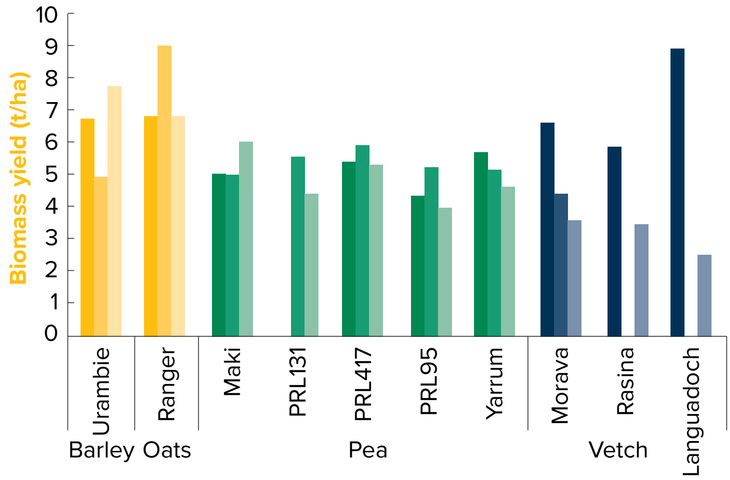

Figure 5: *Comparison of biomass production from 2 forage cereals (orange), 5 field pea cultivars (green), and 3 vetch cultivars (blue) at 3 sites in 2010 in south-western Qld; Billa Billa sown on 10 June (medium colour), Billa Billa sown 18 July (light colours) and Inglestone (darkest colours).*

Yield Prophet®

Australia's climate, and in particular rainfall, is among the most variable on earth; consequently, crop yields vary from season to season. In order to remain profitable, crop producers must manage their agronomy, crop inputs, marketing and finance to match each season's yield potential. Scientists have aimed to support farmers' capacity to do this by developing APSIM (Agricultural Production Systems Simulator). 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 on-line 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 in decision making. By matching crop inputs with potential yield in a given season, Yield Prophet® subscribers may avoid over- or under- investing in their crop. The simulations provide a framework for farmers and advisers to:

- forecast yield
- manage climate and soil water risk
- make informed decisions about nitrogen 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, applied and influence decision making.

1.9.1 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). [57]

Queensland Alliance for Agriculture & Food Innovation produces regular, seasonal outlooks for grain 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. [58]

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.

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

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

MORE INFORMATION

Climate Kelpie: Decision support tools for managing climate

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. [59]

1.9.2 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. Growers have some control over the stored soil water; i.e. measuring soil moisture before sowing. 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. [60]

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.

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

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

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

- 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. [61]

1.9.3 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).

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.

Vetch has higher WUE than chickpea, but lower than wheat (Table 7).

Table 7: *Water Use Efficiency based on total biomass (WUEdm) or grain yield (WUEgy) of different crops. Water Use Efficiency is based on the biomass or yield per mm of crop water use. Values are mean and range.*

Crop	Region	WUEdm	WUEgy
		(kg/ha.mm)	
Canola	Victoria	24.0 (17.1–28.4)	6.8 (4.7–8.9)
Canola*	NSW		13.4
Chickpea	Western Australia	16.0 (11.1–18.3)	6.2 (2.6–7.7)
Lentil		12.7 (8.5–16.7)	6.7 (2.4–8.5)
Lupin		17.3 (9.3–22.3)	5.1 (2.3–8.3)
Faba		24.2 (18.7–29.6)	10.4 (7.7–12.5)
Pea		26.2 (17.6 – 38.7)	10.5 (6.0–15.9)
Vetch		18.2 (13.4–22.4)	7.5 (5.6–9.6)
Chickpea	Tel Hadya, Syria	13.7 (9.4–18.1)	3.2 (2.1–5.2)
Lentil		8.7 (5.0–14.2)	3.8 (1.9–5.5)
Wheat	South Australia	36.1 (21.2–53.1)	15.9 (9.2–23.2)
	SE Australia		9.9 (max = 22.5)

Source: GRDC

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

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 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. [62]

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. [63]

1.9.4 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

VIDEOS

WATCH: GCTV12: Water Use Efficiency initiative.

WATCH: GRDCTV10: Grazing stubbles and Water Use Efficiency.

62 GRDC (2009) Water Use Efficiency fact sheet. Grains Research and Development Corporation, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/02/water-use-efficiency-north

63 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

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. [64]

In southern NSW, experiments showed that banding of anhydrous ammonia or urea fertiliser provided a slow-release form of N to 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. [65]

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 WhopperCropper) and The Nitrogen Books. [66]

1.9.5 Double crop options

Conservative cropping systems, where crops are only planted when soil moisture levels are high, will result in high individual crop yields but relatively fewer crops and long, inefficient fallow periods. More aggressive cropping systems that include double cropping will result in a greater number of lower-yielding crops and generally more efficient use of available rainfall. The appropriate balance between aggressive and conservative systems will depend on a whole range of factors, including a grower's attitude to risk, and is the subject of ongoing research.

Double cropping into a summer forage out of a winter legume or cereal could be an effective way to break out of a winter crop rotation for 18 months – 2 years to allow control of winter crop weeds and diseases and use of alternative herbicide chemistry. The summer forage would allow some return to be achieved as opposed to a long fallow (12 months) leading into and out of summer crop (e.g. grain sorghum) in the sequence.

Vetch can bring benefits to double-cropping sequences (Table 8).

Vetch is tolerant to the triazine group of herbicides (e.g. atrazine) enabling it to be double-cropped after sorghum or maize provided that excessively high rates of atrazine have not been used in the preceding summer cereal. Any likelihood of crop damage to the vetch will be further minimised by only planting in situations where there is a reasonable profile of sub-soil moisture at planting (60 cm wet soil). [67]

64 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

65 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

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

67 DAF (2011) Vetches in southern Queensland. DAF QLD. https://www.daf.qld.gov.au/plants/field-crops-and-pastures/pastures/vetches

Table 8: *Summary of relative performance of winter and summer forage crop options for key attributes in grain cropping systems in central west NSW (*** - high, **-moderate, *-low).*

Forage option	Forage production	Grazing tolerance	N inputs	RLN control	Crop weed management	Residual soil water	System role/ fit
Winter forages							
Oats	***	***	-	**	*	**	Alternative to winter grain cereals
Forage brassicas	**	***	-	***	***	**	Replace canola where unviable or risky
Field pea	**	*	**	**	**	***	Replace Chickpea or Fababean, dual-purpose
Vetch	**	***	**	?	**	***	Replace winter pulses
Snail medic	**	***	**	?	**	***	Rotation with cereals, hard seed problem
Sulla		***	***	?	**	*	2–3 year phase, alternative to lucerne
Summer forages							
Forage sorghum	****	***	-	**	***	**	Transition to summer crop phase
Millet	***	**	-	***	***	***	Soil cover after winter pulses, dual-purpose
Lablab	***	**	***	***	**	**	Alternative to mungbeans
Cowpea	**	*	**	**	**	**	Alternative to mungbeans
Soybeans	***	*	***	*	**	**	Dual-purpose alternative to mungbeans

Source: GRDC

MORE INFORMATION

Likely fit of summer and winter forage crop options in central west farming systems

Choosing rotation crops – Fact Sheet

Companion species

Vetch can be grown in mixtures with annual ryegrass, volunteer cereals or sown cereals for grass/legume pasture or hay production, and with a range of summer growing grasses in the subtropics.

In Europe vetch is grown as a 'companion' crop between rows of maize and sunflower to provide nitrogen to these crops.

Vetches as an annual legume can be grown with perennial legumes to provide more bulk and feed in the first year of seeding. [68]

68 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

1.10 Disease status of paddock

Vetch is sensitive to damage from rusts, ascochyta blight and botrytis grey mould, and management action should be taken in paddocks that have a history of these diseases or are at high risk of incurring these diseases.

To limit the risk of disease in vetch and other pulses in the cropping sequence, vetch should be limited to no more than once in every four years in a particular paddock. [69]

Potential high-risk paddocks include those with bare patches, uneven growth and white heads in the previous crop; paddocks with unexplained poor yield from the previous year; newly purchased or leased land; and particular crop sequences. Very high rainfall in the previous year can also increase the likelihood of disease. [70]

1.10.1 Soil testing for disease

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

PreDicta B

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.

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.

1.10.2 Cropping history effects

Inoculum levels can build up over one year and paddocks may be vulnerable if conditions are conducive to disease. It is therefore important that growers know what the risk of soil-borne disease is before they begin sowing crops. By knowing which soil-borne pathogens pose a significant risk to broadacre crops prior to seeding, extensive losses can be avoided.

High risk cropping history includes; cereals on cereals or following grassy pastures; durum crops (e.g crown rot inoculum); and paddocks coming out of chickpeas (*Pratylenchus sp.* populations). [71]

Vetch (and other legumes) sown in the paddock in the previous four years can increase the risk of disease.

For more information, see Section 9: Diseases.

69 R Matic (2010) Vetch summary 2010. SARDI. Online Farm Trials. http://www.farmtrials.com.au/trial/14055

70 GRDC (2017) GroundCover Issue 127: Prepare for elevated 2017 disease levels. https://grdc.com.au/resources-and-publications/groundcover/groundcover-issue-127-marchapril-2017/prepare-for-elevated-2017-disease-levels

71 GRDC (2017) GroundCover Issue 127: Prepare for elevated 2017 disease levels. https://grdc.com.au/resources-and-publications/groundcover/groundcover-issue-127-marchapril-2017/prepare-for-elevated-2017-disease-levels

1.11 Nematode status of paddock

Root-lesion nematodes (RLNs)can cause yield decline in many crops. Vetch is moderately susceptible to *Pratylenchus neglectus* and susceptible to *P. thornei*. Bitter vetch is thought to be resistant to *P. neglectus*. [72] Avoid sowing vetch into paddocks that have a history of RLNs.

Small numbers of the oat race of stem nematode can sometimes be found in Blanchefleur, Languedoc and Namoi vetch. [73]

1.11.1 Nematode testing of soil

PreDicta B should be used to test soil to nematodes prior to sowing.

For more information, see Section 1.9.1 Soil testing for disease, above.

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

1.11.2 Effects of cropping history on nematode status

Intensive cropping of susceptible crops—particularly wheat—will lead to an increase in RLN levels in the soil. Populations build up in the soil over time and damage susceptible crops in a sequence.

When RLN are detected, rotations and variety choice are central to successfully reducing RLN populations. Only nonhost crops or resistant varieties will minimise the build-up of RLN. Tolerant crops will suffer less damage, but if these varieties are susceptible, RLN numbers can still increase. Aim to reduce populations to less than 2/g soil.

When very high populations of RLN are detected, it may take two or more resistant crops grown consecutively in rotation to reduce populations. Re-testing of soil after growing resistant crops is recommended, so that crop sequences can be adjusted if populations are still at damaging levels. Avoid very susceptible crops and varieties. [74]

For more information, see Section 8: Nematodes.

1.12 Insect status of paddock

In early growth stages vetches are sensitive to redlegged earth mite, and lucerne flea, and in mid to later growth to cowpea aphids as well to Native budworm at flowering and podding stages. [75]

1.12.1 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.

72 V Vanstone, J Lewis (2009) Plant parasitic nematodes – Fact sheet. GRDC. https://grdc.com.au/__data/assets/pdf_file/0018/224424/plant-parasitic-nematodes-south-and-west.pdf.pdf

73 S Taylor. GRDC GroundCover Issue 22: Stem nematode. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-issue-22/stem-nematode

74 GRDC (2015) Tips and Tactics: Root-lesion nematodes, Northern region. www.grdc.com.au/TT-RootLesionNematodes

75 R Matic, S Nagel, G Kirby (2008) Common Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Common_vetch.htm

- However, be aware of cultural practices that favour pests and rotate crops each year to minimise the build-up of pests and plant diseases. [76]

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.

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. [77]

1.12.2 Effect of cropping history

It is important to consider paddock history when planning for pest management. Resident pests can be easier to predict by using paddock history and agronomic and weather data to determine the likely presence (and numbers) of certain pests within a paddock. This will point to the likely pest issues and allow growers to implement preventive options. [78] Reduced tillage and increased stubble retention have changed the cropping landscape with respect to soil moisture retention, groundcover and soil biology and this has also affected the abundance and types of invertebrate species being seen in crops. These systems increase invertebrate biodiversity but also create more favourable conditions for many pests such as slugs, earwigs, weevils, beetles and many caterpillars. In turn, they have also influenced beneficial species such as carabid and ladybird beetles, hoverflies and parasitic wasps. [79]

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. [80]

MORE INFORMATION

Pest Genie Australia

APVMA.

76 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

77 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

78 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

79 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

80 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

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

- Weedy fallows and volunteer crops encourage soil insect 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. [81]

See Section 7: Insect control, for more information.

81 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