NORTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

# CEREAL RYE

## SECTION 10

## PLANT GROWTH REGULATORS AND CANOPY MANAGEMENT

PLANT GROWTH REGULATORS | CANOPY MANAGEMENT | THE FUTURE OF CANOPY MANAGEMENT IN THE NORTHERN GRAINS REGION

# Plant growth regulators and canopy management

## Key messages

- In Australian cereal production, plant growth regulators (PGRs) are mostly used with the intention of producing a smaller plant that is resistant to lodging, or with the intention of reducing excessive growth in irrigated broadacre crops.
- Trials have revealed mixed responses in crop yield to the application of PGRs.
- Canopy management includes a range tools to help manage crop growth and development with the aim of maintaining canopy size and duration to optimise photosynthetic capacity and grain production.
- Canopy management starts at seeding: sowing date, variety, plant population and row spacing are fundamental. There is more to it than delaying the application of nitrogen.
- So far the best results for canopy management in the northern region have been seen in early sown, long-season varieties with high yield potential and which are very responsive to N with high N-fertiliser inputs. [1]

## 10.1 Plant growth regulators

A plant growth regulator (PGR) is an organic compound, either natural or synthetic, that modifies or controls one or more physiological processes within a plant. They include many agricultural and horticultural chemicals that influence plant growth and development . PGRs are intended to accelerate or retard the rate of growth or maturation, or otherwise alter the behaviour of plants or their produce. [2] This influence can be positive, e.g. larger fruit or more pasture growth, or negative, e.g. shorter stems or smaller plant canopies. [3]

The use of PGR products in Australia has generally been relatively low. The principle reason for this is simply that crop responses are viewed as variable, and growers have not seen enough benefit in incorporating them into their cropping programs.

The most widely used PGRs in Australia have a negative influence on plant growth; i.e. they are applied with the intention of producing a smaller plant that is resistant to lodging or with the intention of reducing excessive growth in irrigated broadacre crops. Currently, there are four broad groups of PGRs in use in Australian crops. They are:
Ethephon, e.g. Ethrel®.

1. Onium-type PGRs, e.g. Cycocel®, the active ingredient of which is chlormequat (and Pix®, which is registered only for cotton).
2. Triazoles, e.g. propiconazole (which is registered as a fungicide, and not for use as a PGR).
3. Trinexapac-ethyl, e.g. Moddus®, Moddus® Evo.

The four groups of PGRs act by reducing plant cell expansion, resulting in, among other things, shorter and possibly thicker stems. If the stems are stronger and shorter, the crop is less likely to lodge.

Ethephon is applied from the stage of the flag leaf emerging (Z37) to booting (Z45), and reduces stem elongation through the increase in concentration of ethylene gas in the expanding cells.

---

1 G McMullen (2009) Canopy management in the northern grains region: the research view. NSW DPI. http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-.pdf

2 PG Lemaux (1999) Plant growth regulators and biotechnology. Presentation, Western Plant Growth Regulator Society, http://ucbiotech.org/resources/biotech/talks/misc/regulat.html

3 D Jones (2014) Plant growth regulators. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

The PGRs in groups two to four reduce crop height by reducing the effect of the plant hormone gibberellin. These are applied at early stem elongation (Z30–32).

The manufacturers of these products claim other benefits, too, including:

- Better root development that allows for increased root anchorage.
- Better root development that provides greater opportunity for water and nutrient scavenging.
- Possible improved grain quality.
- Reduction in shedding in barley.
- Increased harvest index (HI), the ratio between grain and total dry matter.
- Faster harvest speeds and reduced stress at harvest.

A combination of trinexapac-ethyl and chlormequat applied at growth stage 31 has been found to provide significant and consistent yield gains in wheat (11%) and barley (9%) under dry spring conditions. They also significantly reduced plant height, lessening the possibility of lodging in wetter seasons. [4] Overseas, chlormequat chloride has been found to inhibit gibberellin production, and has been recommended in winter and spring rye, wheat, oats, triticale and winter barley. [5]

Moddus® is registered for ryegrass seed crops, poppies and sugar cane. Moddus Evo®, an enhanced dispersion concentrate of Moddus®, is not currently registered but has been submitted to the Australian Pesticides and Veterinary Medicines Authority (APVMA) for registration to be used in Australian cereals.

An alternative to the chemical PGRs is grazing. It was demonstrated in the Grain and Graze project, which had study sites at a number of mixed-farming locations, that grazed treatments were regularly shorter than the non-grazed treatments, and grazed crops were less prone to lodging. [6]

## MORE INFORMATION

Plant growth regulators

Plant growth regulators in broad acre crops

Plant growth regulators and their agronomic and economic benefits to high yield potential cereal, pulse and oilseed crops

### 10.1.1 Considering mixed results

In Australia there have been mixed results in the ability of PGRs to increase yield, and therefore profits.

The most important things to remember about PGRs are:

- Crop responses to the use of plant growth regulators (PGRs) can be inconsistent.
- In general, yield responses, if any, are produced by the reduction in lodging rather than as a direct effect of the PGRs.
- Plant growth regulators must be applied at the correct crop growth stage, according to product directions, which may be well before any lodging issues become apparent.

Attempting to grow high-yielding irrigated crops requires high levels of inputs, including water and fertiliser, which can promote large vegetative crops that increase the risk of lodging. Lodging is considered one of the biggest barriers to reliably achieving high yields in intensive cereal production in Australia. It can result in reduced yields and a difficult harvest. Plant growth regulators have been used for many years, but results can be variable, even having negative effects on yield. The ICC conducted trials in 2003 and 2004 in which there was some reduction in lodging but little yield gain. At the same time, trials on nitrogen (N) management in cereals demonstrated that, to achieve high yields, crops do not necessarily need to be sown at heavy rates and with large amounts of nitrogen, which give a correspondingly lush crop early in the season, but one that is prone to lodging. This has seen many growers adopt a topdressing tactic that supplies the crop with N when it needs it, i.e. from stem elongation onwards. Less vegetation at stem elongation promotes stronger stems, which can support a crop that yields 8 t/ha.

4 W Long (2005) AC0003: Plant growth regulators and their agronomic and economic benefits to high yield potential cereal, pulse and oilseed crops. Final Report. Project ACC00003. GRDC, http://finalreports.grdc.com.au/ACC00003

5 BASF. How do PGR's work? http://www.agricentre.basf.co.uk/agroportal/uk/en/crop_solutions/cereals_5/lodging___canopy_managememt/canopy_management_in_cereals.html

6 D Jones (2014) Plant growth regulators. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

A trial conducted at the ICC trial block in 2012 which aimed to grow 10 t/ha of wheat and barley was deliberately sown heavily and fertilised early, and sprayed with the plant growth regulator, Moddus® Evo, as lodging was likely to occur. The effect of the PGR was mixed: barley yields increased, but wheat yields did not, despite the crops not actually lodging. A repeat trial sown in 2013 saw some lodging control and, once again, a yield increase in barley.

### Conclusions: The value of PGRs

PGRs may have a place in the management of high-yielding crops. Unfortunately, their effects are not consistent and the decision whether to apply a PGR has to be made at approximately three months before the lodging would be expected.

Other chemicals that have a PGR effect are available but are not yet registered for use on all crops or at rates and timings that would have a regulatory effect on growth.

The yield improvements seen in barley in the ICC trials need further investigation, as the reason behind the yield increase is not clear. [7]

MORE INFORMATION

Mixed bag: dual purpose crops, PGRs and other local research

## 10.1.2 Case study: using Moddus® Evo

Key points:

- Moddus® Evo reduces lodging and can increase yields.
- Application, timing and concentration are critical.
- Moddus® Evo should not be applied to stressed plants.
- Moddus® Evo has better formulation stability and plant uptake

Lodging is considered one of the biggest barriers to reliably achieving high yields in intensive cereal production in Australia. Cereal rye can be prone to lodging. When favourable season conditions combine with traditional management practices in high input cereal production systems, lodging can result in significant reductions in yield and grain quality.

Moddus® (250 g/L trinexapac-ethyl) is used by cereal growers in a number of other countries, including New Zealand, UK and Germany, to reduce the incidence and severity of lodging and to optimise the yield and quality of high-yielding cereal crops. Moddus® Evo is a formulation with an enhanced dispersion concentrate (DC) which has been developed to provide greater formulation stability and more effective uptake in the plant. With improved mixing characteristics and the potential to provide better consistency of performance Moddus® Evo is currently before the APVMA for registration for use in Australian cereals.

GRDC and Syngenta, the manufacturer of Moddus®, undertook research to investigate the value of Moddus® applications to Australian cereals to reduce lodging and improve yields. [8]

### Methods

The researchers conducted field trials across Australia from 2004 to 2011. They used a number of varieties, climatic conditions and geographical locations. They established small plots, typically 20–120 $m^2$ using a randomised complete block design, and incorporating three to six replicates.

They measured the effect of Moddus® application on plant growth, stem strength, stem-wall thickness, lodging, lodging score, and yield, and took grain-quality measurements.

7 D Jones (2014) Plant growth regulators. GRDC Update Paper. GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators

8 LM Forsyth and K McKee (2013) Moddus Evo: controlling plant growth for reduced lodging and improved cereal yields. GRDC Update Paper. GRDC, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2013/03/moddus-evo-controlling-plant-growth-for-reduced-lodging-and-improved-cereal-yields

MORE INFORMATION

Moddus Evo: Controlling plant growth for reduced lodging and improved cereal yields

### Results

In the trials, overall improvements in yield were often correlated with a reduction in stem height, irrespective of whether lodging had occurred. Yield improvements through the reduction of lodging are well documented. What is less understood is the often-positive impact on yields with the use of Moddus® Evo in the absence of lodging.

Conversely during the course of the evaluation of Moddus® Evo on the yield enhancement and reduction in lodging, a few trials gave anomalous results, in which the application of Moddus® Evo did not improve yield. When the researchers examined these trials, they found that either environmental conditions during the lead-up to the application of the chemical were poor—with extensive frosting, drought, poor subsoil moisture,—or there were nutrient deficiencies in the crop. As a result, they recommended that Moddus® Evo should only be applied to healthy crops with optimum yield potential. As well, the timing and concentration of Moddus® Evo applications is critical to produce the optimal yield improvements.

Moddus® Evo offers growers in environments conducive to lodging an in-season option to reduce the impact of lodging while allowing them to manage crops for maximal yields.

## 10.2 Canopy management

Key points:

- Canopy management starts at seeding, and involves sowing date, variety, plant population and row spacing are fundamental, not just delaying the application of nitrogen.
- The correct identification of the key growth stages for input application is essential, particularly during early stem elongation when the most important leaves of the crop canopy emerge.
- Knowledge of soil-moisture status and the reserve and supply of soil nitrogen need to be taken into account in order to match canopy size to environmental conditions.
- Crop models can help growers and advisers to integrate information on crop development, environmental conditions and nutrient status so they can make better canopy management decisions. [9]

### 10.2.1 What does canopy management entail?

The concept of canopy management has been developed primarily in Europe and New Zealand, both distinct production environments to those typically found in the grain-producing regions of Australia, and especially the northern grains region. Canopy management incorporates the use of a number of tools to manage crop growth and development—sowing date, choice of variety, density of plant population, row spacing, and aspects of nitrogen (N) application—so as to maintain canopy size and duration in order to optimise photosynthetic capacity and grain production (Photo 1). [10]

One of the main tools growers use to manage the crop canopy is the rate and timing of the application of nitrogen (N) fertiliser. The main difference between canopy management and previous N topdressing is that, in the canopy management all or part of the N inputs are tactically delayed until later in the growing season. The delay tends to reduce early crop canopy size, but the canopy is maintained for longer, as measured by green-leaf retention during the grain-filling period, and tends to give higher yields. [11]

9 GRDC (2009) Cereal canopy management more than delayed nitrogen. Fact sheet. GRDC, https://grdc.com.au/__data/assets/pdf_file/0014/202523/canopy-management.pdf.pdf

10 N Poole (2005) Cereal growth stages. GRDC, https://www.researchgate.net/file.PostFileLoader.html?id=5780fa6bf7b67e860b4def31&assetKey=AS%3A381929540079624%401468070506798

11 G McMullen (2009) Canopy management in the northern grains region: the research view. NSW DPI, http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-.pdf

**Photo 1:** *Examples of controlled canopy cover. Left: with thinner crop canopy, yield = 6.18 t/ha and 12% protein. Right: with thicker crop canopy, yield = 6.20 t/ha and 10.6% protein. Plots sown to Kellalac wheat 11 June 2009 in Gnarwarre (Geelong region), in high rainfall zone, and treated with same level of nitrogen.*

Photos: GRDC

By adopting canopy-management principles and avoiding excessively vegetative crops, growers may be able to realise a better match of canopy size with yield potential, as defined by the water available.

However, canopy management is not about a delayed N strategy: it starts at seeding, by determining the correct plant establishment for the chosen seeding date and row spacing. This must take into account available soil moisture and nutrients (Figure 1). [12]

Other than sowing date, plant population is the first point at which the grower can influence the size and duration of the crop canopy. [13] One of the main tools for growers to use is the rate and timing of applied fertiliser N.

If the canopy becomes too big, it competes with the growing heads for resources, especially during the critical 30-day period before flowering. This is when the main yield component, grain number per unit area, is set. Increased competition from the canopy with the head may reduce yield by reducing the number of grains that survive for grainfill.

After flowering, temperature and evaporative demand increase rapidly. If there is not enough soil moisture, the canopy dies faster than the grain develops, and results in small grain. Excessive N application and high seeding rates are the main causes of excessive vegetative production. Unfortunately, optimum N and seeding rates are season-dependent. Under drought conditions, N application and seeding rates that would be regarded as inadequate under normal conditions may maximise yield, whereas higher input rates may result in progressively lower yields. Alternatively, in years of above-average rainfall, yield may be compromised with normal input rates. At the extreme, excessive early growth results in haying-off. In this situation, a large amount of biomass is produced using a lot of water and resources, then later in the season, there is insufficient moisture to keep the canopy photosynthesising and there are not enough stored water-soluble carbohydrates to fill the grain. Therefore, grain size and yield decrease.

To attain maximum yield, it is important to achieve a balance between biomass and resources. The main factors that can be managed are:

- plant population
- row spacing
- inputs of N

12 GRDC (2009) Cereal canopy management more than delayed nitrogen. Fact sheet. GRDC, https://grdc.com.au/__data/assets/pdf_file/0014/202523/canopy-management.pdf.pdf

13 N Poole (2005) Cereal growth stages. GRDC, https://www.researchgate.net/file.PostFileLoader.html?id=5780fa6bf7b67e860b4def31&assetKey=AS%3A381929540079624%401468070506798

- sowing date
- weed, pest and disease control
- plant growth regulation with grazing or specific plant growth regulator products

Of these, the most important to canopy management are N, row spacing and plant population. [14]

Applying N or fungicide at stem elongation increases the opportunity to match input costs to the potential yield for that season. While seeding applications may still be required for healthy establishment, crop models help support decisions on application timing. Models such as APSIM and Yield Prophet® simulate growth stage and season.

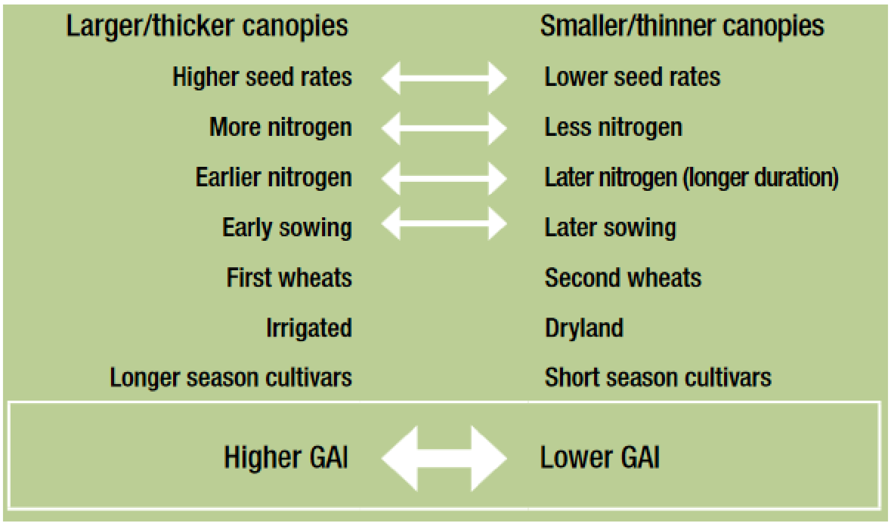


**Figure 1:** *Factors under grower control that influence canopy density, size and duration. (GAI = green area index, the amount of green surface area.)*

Source: GRDC.

The timing and rate of N application should also be considered in conjunction with the inter-related factors of:

- soil moisture
- soil-nitrogen reserves
- seeding date
- seed rate and variety

To practice canopy management it is important to understand the principal interactions between plant-growth stages, available water and nutrients, and disease pressure. These interactions are complex but tools from simple visual indicators through to crop models can assist.

## Cereal canopy management in a nutshell

1. Select a target head density for your environment (350 to 400 heads per square metre should be sufficient to achieve optimum yield, even for yield potential of 7 t/ha).
2. Adjust canopy management based on paddock nutrition, history and seeding time to achieve target head density.
3. Established plant populations for cereals of between 80 and 200 plants/m$^2$ would cover most scenarios.
4. Lower end of range, 80–100 plants/m$^2$—for earlier sowings and high fertility and/or low yield potential low-rainfall environments.

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

5. Higher end of the range, 150–200 plants/m$^2$—for later sowings, lower fertility situations and/or higher-rainfall regions.
6. During stem elongation (GS30–39), provide the crop with necessary nutrition (particularly N at GS30–33 pseudo-stem erect – third node), matched to water supply and fungicides to:
7. maximise potential grain size and grain number per head;
8. maximise transpiration efficiency;
9. ensure complete radiation interception from when the flag leaf has emerged (GS39); and
10. keep the canopy green for as long as possible following anthesis.

Keeping tiller numbers just high enough to achieve potential yield will help preserve water for filling the grain and increase the proportion of water-soluble carbohydrates (WSCs). The timing of the applied N during the GS30–33 window can be adjusted to take account of the targeted head number; applications earlier in the window (GS30) can be employed where tiller numbers and soil nitrogen seems deficient for desired head numbers. Conversely, where tiller numbers are high and crops are still regarded as too thick, N can be delayed further until the second or third node (GS32–33), which will result in fewer tillers surviving to produce a head. Much of the research on topdressing N has focused on the role of in-crop N to respond to seasons in which yield potentials have increased significantly due to above-average rainfall. In these situations, research has shown that positive responses can be achieved, especially when good rainfall is received after N application. [15]

## 10.2.2 Setting up the canopy

Research has shown that extra tillers produced by more plants per unit area are more strongly correlated to yield than are extra shoots stimulated by increased nitrogen at seeding.

Boosting tiller numbers with seeding N results in greater tiller loss between stem elongation and grain fill. This occurs specifically in two situations: in low-rainfall, short-season environments; and when soil moisture is limited. In these situations, moisture and nutrient resources are used before the stems lengthen to produce biomass that fails to contribute to grain yield. Indeed, diverting these resources to unsuccessful tillers limits the potential of surviving tillers.

Therefore, identifying the correct population for a particular sowing date, soil-nitrogen reserve and region is the basis for setting up the crop canopy.

## 10.2.3 Soil-moisture status

Under Australian conditions, soil moisture has been identified as the biggest driver of the size and the duration of the cereal-crop canopy. Therefore, an understanding of how much water a soil can hold, and how much water a soil is holding at seeding and stem elongation, are central to canopy management.

See, the Bureau of Meteorology's Australian landscape water balance map for updates on local soil moisture.

The start of stem elongation (GS30) is the pivotal point for deciding on inputs, as from this point canopy expansion is rapid, and nitrogen and water reserves in the soil can be quickly used up.

If soil moisture is limited at the start of stem elongation, the ability to manipulate the crop canopy with nitrogen is limited. In many cases, the best canopy management is not to apply inputs such as nitrogen and fungicides.

Modelling demonstrates that by setting up a smaller crop canopy, growers can reserve limited stored soil moisture for use at grain fill, rather than have it depleted

15 N Poole and J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

by excessive early growth. However, in higher-rainfall regions and in good seasons, setting up a small canopy may result in yields falling below potential.

Calculating potential yield and then plotting actual rainfall against decile readings for the region provides a broad picture of whether there will be sufficient soil moisture to consider additional nitrogen inputs at stem elongation.

The decision-support tool Yield Prophet® offers simple tools to record and assess multiple options that cover the relationship between growing plants and the environment, including available water and nutrients.

### 10.2.4 Soil nitrogen

It is important to have an understanding of soil-N reserves to the depth of the rooting zone. Generally, 40 to 50 kilograms of N per hectare of soil-available N is required to feed a crop to stem elongation (GS30). Higher soil-nitrogen reserves provide much more flexibility in managing the canopy with tactical nitrogen applied during stem elongation.

The timing of deep-soil tests is important. Those carried out in summer, several months before seeding, may reveal less soil nitrogen than tests carried out after the autumn rains, when greater mineralisation will have occurred.

Providing soil moisture has not been limited or the crop has not been subject to waterlogging over winter, crop appearance at GS30–31 gives a reasonable indication of nitrogen reserves, and the justification for nitrogen application at this stage.

However, it is difficult to use visual appearance unless you have a benchmark; this has led to the concept of the N-rich strip (Photo 2). A useful guide that requires no sophisticated equipment is to apply an excess of nitrogen at sowing, e.g. 50–100 kg N/ha, to a small area of the paddock, approximately 2 m by 10 m, and use that as a benchmark. [16]

**Photo 2:** *vA large difference in visual appearance: N-Rich strip (110 kg N/ha at seeding) viewed at GS31 on low soil-N reserve (25 kg N/ha 0–90 cm). Left: 443 tillers/m$^2$ in N-rich soil. Right: 266 tillers/m$^2$ in soil with no extra N enrichment.*

Photos: GRDC

During winter and spring by comparing crop vigour (tiller number) and greenness in these small N-rich areas with the rest of the crop, an indication of N supply can be obtained. The advantage of using the plant rather than depending totally on a soil test is that the plant directly registers soil-N supply, whereas the soil test measures the soil-nitrogen reserve, which crop roots may not always be able to access.

This visual difference can be quantified by using crop sensors that measure the light reflectance from the crop canopy. By measuring the reflectance at the red and near-infrared wavelengths, it is possible to quantify canopy greenness using a number of vegetative indices, the most common of which is termed the Normalised Difference Vegetative Index (NDVI). This index gives an indication of both biomass present and the greenness of that biomass. Canopy sensing can be done remotely from aircraft or satellites, or with a hand-held or vehicle-mounted sensor.

16 GRDC (2009) Cereal canopy management more than delayed nitrogen. Fact sheet. GRDC, https://grdc.com.au/__data/assets/pdf_file/0014/202523/canopy-management.pdf.pdf

## 10.2.5 Seeding rate and date

Achieving the correct plant population is fundamental if sufficient tillers are to be set. Seeding rates need to be adjusted for seed size and planting date; if this does not occur the first step in controlling the canopy is lost.

How many plants are targeted depends on:

- region—as a general guide, drier regions sustain lower plant populations than wetter environments; and
- sowing date—earlier sowings require lower plant populations compared to later sowings, as the tillering window is longer and more tillers are produced per plant.

Overall, earlier planting provides greater opportunities to manipulate the crop canopy during the stem-elongation period: the plant's development periods are extended along with the earlier tillering period.

### Row spacing

Increased interest in no-till farming has created a trend for wider spacing of crop rows (Figure 2).

- In general, increasing row spacing up to 50 cm has minimal effect on cereal yield when yield potential is less than 2 t/ha.
- In higher-rainfall areas, where cereal crops have higher potential yields, significant yield decreases have been recorded with row spacing greater than 25 cm.
- The yields of broadleaf crops vary in response to wider row spacing.
- Precision agriculture allows for easier inter-row sowing and fertiliser applications at wider row spacing. [17]

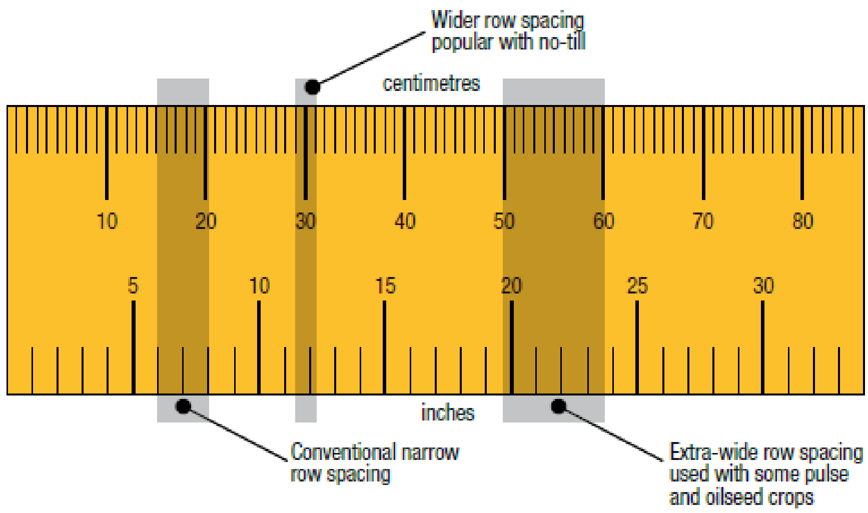


**Figure 2:** *Common row spacings in metric and imperial measurements.*

Source: GRDC.

### Row orientation

The competitive ability of cereal crops can be increased by orientating crop rows at a right angle to the sun light direction, i.e. sow crops in an east-west direction. East-west crops more effectively shade weeds in the inter-row space than north-south crops. The shaded weeds have reduced biomass and seed set. The advantage of this technique is that it's free!

17 GRDC (2011) Crop placement and row spacing: northern region. Fact sheet. GRDC, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2011/02/crop-placement-and-row-spacing-northern-fact-sheet

Consider the weed species in the field. Broadleaf weeds can alter the angle of their leaves to 'track' the sun throughout the day. So while a cereal crop can shade broadleaf weeds, the weeds will still be able to get maximum benefit from any sunlight that reaches them through the crop canopy. Further, any weeds that grow taller than the crop will not be effectively shaded by the crop canopy.

Consider the layout of the paddock. It may not be possible to sow a paddock in an east-west direction, depending of the shape of individual fields.

Consider the location of the paddock. The sun angle in winter is highest at the equator (where the sun is close to being directly overhead at midday). Sun angle becomes lower south of the equator. A low sun angle in winter will cause an east-west crop to cast shade on the inter-row space for a great proportion of the day. Therefore, a crop orientation will have a greater impact in southern Australia, compared to northern Australia.

Using an east-west orientation may be more practical with auto-steer. Without auto-steer, driving directly into the sunrise/sunset for seeding/spraying/harvest of an east-west crop will be unpleasant and potentially dangerous.

Increased shading by an east-west crop reduces the soil surface temperature in the inter-row space and reduces evaporation, leading to increased soil moisture. This increased moisture occasionally increases crop yield where moisture is limited. However, the cool, moist environment of the inter-row space may influence the development of crop disease in some locations (although altered levels of disease have not been noted in previous trials). [18]

## Yield

- There are a number of reasons why growers might wish to pursue wider row spacing in cereals, e.g. residue flow, and inter-row weed and disease control. However, in canopy-management trials (2007–10) in a wide range of rainfall scenarios, increasing row width reduced yield. [19]
- The yield reduction was particularly significant when row width exceeded 30 cm.
- Crop row spacing is an important factor in managing weed competition (Photo 3). [20]
- At row widths of 30 cm, the reduction in yield compared to narrower 20–22.5 cm row spacing was dependent on overall yield potential.
- At yields of 2–3 t/ha the yield reduction was negligible.
- At yields of 5 t/ha the yield reduction was 5–7%, and averaged about 6%.
- Data from a single site suggest that rotation position may influence the yield response in wider row spacing. Continuous cereal plantings suffered less yield reduction with wider rows than an equivalent trial at the same site which including wheat after canola. [21]

18 Borger C. (2016). East-west orientation for improved crop competition. DAFWA. https://www.agric.wa.gov.au/grains-research-development/east-west-orientation-improved-crop-competition

19 N Poole and J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

20 Weedsmart (2015) Narrow row spacing: is it worth going back? Weedsmart, http://weedsmart.org.au/narrow-row-spacing/

21 N Poole and J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

**Photo 3:** *Narrow row spacing (left) and wide row spacing (right). The higher the yield potential, the greater the negative impact of wider rows on crop yields.*

Photos: Weedsmart

## Plant spacing

- Increasing row width decreases the plant-to-plant spacing within the row, leading to more competition within the row and reduced seedling establishment (for reasons that are not clearly understood).
- Increasing plant populations when using wider rows can be counterproductive with regard to yield, particularly where plant populations exceed 100 plants per square metre as a starting point.
- Limited data indicate that increasing seeding rates so that the average plant-to-plant spacing in the row drops below 2.5 cm are either negative or neutral in terms of grain yield.
- Planting seed in a band (as opposed to a row) will increase plant-to-plant spacing but may also increase weed germination and moisture loss through greater soil disturbance. [22]

## Dry matter

- Wider row spacing (30 cm and over) reduced harvest dry matter relative to narrower rows (22.5 cm and under), with differences growing steadily (in kilograms per hectare) from crop emergence to harvest, by which time differences were in the order of 1–3 t/ha depending on row width and growing-season rainfall.
- The reduction in dry matter in wide rows was also significant at flowering (GS60–69), frequently 1 t/ha reduction when row spacing increased 10 cm or more over a 20 cm row-spacing base. This could be important when considering harvesting for hay rather than grain. [23]

## Grain quality

- The most noticeable effect of row width on grain quality was on protein: wider rows reduced yield and increased grain protein.
- Differences in grain quality were typically small in terms of test weights and screenings, with very small benefits to wider rows over narrow rows on some occasions. [24]

## Nitrogen management

Nitrogen management has not been found to interact with row spacing, so optimum N regimes for narrow row spacing (22.5 cm or less) can be the same as for wider row spacing (30 cm or more). The greater nitrogen efficiency observed with N applied

22 GRDC. (2014). Advancing the management of crop canopies. https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

23 N Poole and J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

24 N Poole and J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

at stem elongation was more important with narrow row spacing, since higher yields lead to a tendency for lower protein. [25]

## 10.2.6 In-crop nitrogen

Delaying N inputs from seeding to stem elongation (GS30–31) means they can be better matched to the season. So, in a dry spring, no application may be warranted. In spring, with adequate rainfall to justify N application, project trials have shown stem-elongation N to give yields equal to or better than wheat crops grown with seeding N. However, applying N in advance of a rain front to ensure good incorporation has been found to be more important than applying it at an exact growth stage. While GS31 should be the target growth stage for in-crop N application, the window can be expanded from GS25–31 in order to take advantage of rainfall. Even applications delayed until flag leaf can be successful where starting soil nitrogen is not too low (Figure 3). [26]

Figure 3 presents the results from winter cereal cropping trials across Australia that investigated the use of in-crop solid nitrogen at stem elongation. The trials showed that where soil nitrogen reserves are low, N applied at stem elongation is not always the most appropriate strategy if yield is to be optimised. Stem-elongation N applications were found to be less appropriate with shorter-season varieties and late-sown crops. Drought conditions during the trial period (2006 to 2008) limited the results of these trials. These trials assessed stem elongation N use in cereals grown on wider-row spacings 30–35 cm compared to 17.5–20 cm. However, at the same seeding rate, moving to wider rows was found to reduce tillers per unit area, and final ear population and yield, the latter by approximately 6% in the high-rainfall zone (HRZ).

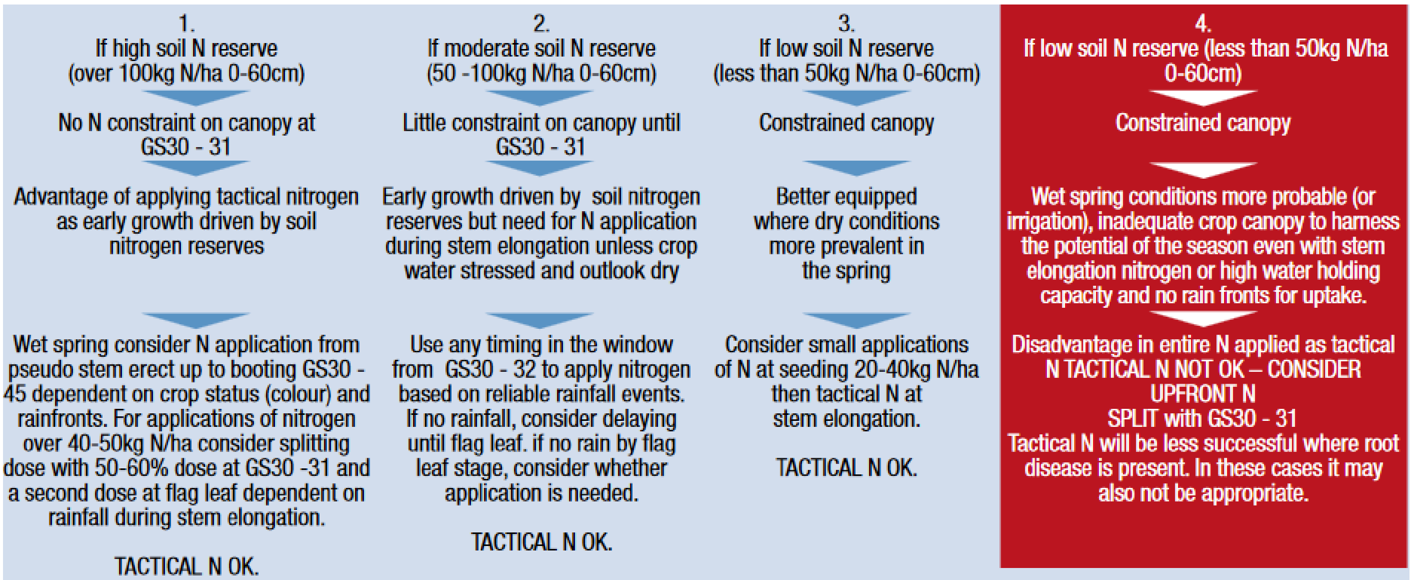


**Figure 3:** *Broad scenarios based on soil nitrogen level.*

Source: GRDC

## 10.2.7 Limitations of tactical nitrogen application

The main limitation to tactical N application in the Northern region is the ability to reliably apply N before a rain event, when it would be applied to enable roots to access soluble N in the root-zone. Predicted rain fronts may pass without yielding anything; therefore, dependably applying N throughout the season is risky.

25 N Poole and J Hunt (2014) Advancing the management of crop canopies. GRDC, https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/gc105-canopymanagement

26 GRDC (2009) Cereal canopy management more than delayed nitrogen. Fact sheet. GRDC, https://grdc.com.au/__data/assets/pdf_file/0014/202523/canopy-management.pdf.pdf

Foliar N application is gaining popularity; however, this is only suitable for relatively low rates of N addition. Where higher N input is required, an efficient system to apply N into the wet soil profile, after a rainfall event, needs to be devised.

As technologies such as NDVI imaging and paddock management in zones become prevalent, the addition of N later in the crop cycle will become more relevant and will force the development of equipment to make such a system work.

By combing knowledge gained from the results of trials and from paddock experience, the aim of improving the economic outcome of the season by manipulating the most costly input in a sophisticated way is becoming a reality. Adoption of these techniques throughout the northern cropping zone would be further aided by the development of efficient, in-soil N-application equipment.

The question is, can canopy management work under Australian conditions—especially the shorter growing season of northern NSW?
Results from southern regions have showed some potential to be applied in the Northern region. This is especially so in areas with high yield potential (although this also means higher N inputs) but further research is required to test and validate the principles in the Northern region. [27]

## 10.3 The future of canopy management in the Northern grains region

In the past much of the research on topdressing nitrogen (N) in northern NSW has focussed on the role of in-crop N to respond to seasons in which yield potentials have increased significantly after above-average rainfall. In these situations research has shown that good responses can be achieved, especially when good rainfall is received after N application.

Recently, though, there has been significant interest in the role of canopy-management principles for crop production in the northern grains region. To increase knowledge about the response of cereal crops to these principles, a research group that includes NSW DPI, the Northern Grower Alliance, AgVance Farming, and Nick Poole from the Foundation for Arable Research in New Zealand, have been conducting trials since 2006. This work is funded by GRDC, and has focussed on the interaction between delayed N applications in high-yielding crops on the Liverpool Plains.

Results from three years of supplementary irrigated research have provided important pointers for the use of canopy management principles in northern NSW. Tactically delaying N is a management system that gives growers the flexibility to respond to seasonal conditions and to manage climate variability. Research has shown that N fertiliser has been able to be delayed until stem elongation (GS31) without yield loss and usually with increased grain protein when conditions are suitable. This means that growers are able to apply a portion of the expected N requirement, and then assess yield potential, as influenced by soil water and seasonal forecasts, later in the season, and respond accordingly. To date, the best results with this approach have been seen in early sown, long-season varieties with high yield potential, as they are very N responsive with high N fertiliser inputs. [28]

Though the trials do not test the effect on cereal rye specifically, recommendations may be applicable to cereals more broadly. Make sure to consult with your local agronomist.

### MORE INFORMATION

For details on the trials, see Canopy management in the northern grains region: the research view

Defining guidelines for canopy management in barley for the different climatic regions of Australia

Cereal canopy management more than delayed nitrogen

Cereal growth stages

Advancing the management of crop canopies

27 McMullen G. (2009) Canopy management in the Northern Grains region. NSW DPI. http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-.pdf

28 G McMullen (2009). Canopy management in the northern grains region: the research view. NSW DPI, http://www.nga.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-.pdf