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# TRITICALE

## SECTION 10

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## PLANT GROWTH REGULATORS AND CANOPY MANAGEMENT

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PLANT GROWTH REGULATORS (PGRS) | CANOPY MANAGEMENT

# 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 they are applied 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 of crop management tools to manage crop growth and development to maintain 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. It is more than purely delaying nitrogen.
- So far the best results for canopy management have been seen in early sown – long season varieties with high yield potential which are very N responsive with high N fertiliser inputs.<sup>1</sup>

## 10.1 Plant growth regulators (PGRs)

A plant growth regulator (PGR) is an organic compound, either natural or synthetic, that modifies or controls one or more specific physiological processes within a plant. PGRs are any substance or mixture of substances intended, through physiological action, to accelerate or retard the rate of growth or maturation, or otherwise alter the behavior of plants or their produce.<sup>2</sup>

The growth of triticale seedlings from seeds treated with three concentrations of the plant growth regulators (PGRs), tetrcyclacis and chlormequat, with or without drying after soaking has been investigated. Both tetrcyclacis and chlormequat inhibited shoot growth. They reduced shoot:root ratios, first by restricting shoot growth (one week after treatment) and later by boosting root growth (eight weeks after transplanting). At the concentrations used tetrcyclacis was a more active PGR than chlormequat and promoted tiller production. Drying, after soaking, promoted root growth, retarded the elongation growth of seedlings and enhanced some of the effects of the PGRs.<sup>3</sup>

In another study, seeds of triticale and barley were soaked in a range of dilutions of chlormequat. Germination was monitored and the growth of seedlings assessed for up to five weeks. Some concentrations of chlormequat produced seedlings with significantly more leaves on the main stem, more primary tillers, a greater leaf lamina area and a higher shoot dry weight. It is argued that these modifications could lead to an increased yield potential.<sup>4</sup>

In Australia there have been mixed results in terms of PGR ability to increase yield and profits.

### Take home messages:

- 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 (Photo 1).

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

<sup>2</sup> Lemaux P. (1999). Plant growth regulators and biotechnology. <http://ucbiotech.org/resources/biotech/talks/misc/regulat.html>

<sup>3</sup> Yang, W., & Naylor, R. E. L. (1988). Effect of tetrcyclacis and chlormequat applied to seed on seedling growth of triticale cv. Lasko. *Plant growth regulation*, 7(4), 289–301.

<sup>4</sup> Naylor, R. E., Brereton, P. S., & Munro, L. (1989). Modification of seedling growth of triticale and barley by seed-applied chlormequat. *Plant growth regulation*, 8(2), 117–125.

- In ICC trials however, yield increases that may be attributed directly to the use of PGRs have been measured in barley but not wheat.
- Plant growth regulators must be applied at the correct crop growth stage according to product directions, which can be well before any lodging issues are apparent.



**Photo 1:** Severe lodging of a cereal crop (left).

Source: [Syngenta](#)

The main commercial triticale varieties are relatively tall compared with newer wheat varieties, increasing the likelihood of lodging. However, in most of the newer varieties lodging is not considered a problem. The likelihood of lodging is increased by high rates of nitrogen fertiliser and under irrigated conditions.<sup>5</sup> PGRs may help to decrease the risk of lodging in triticale, however, this has not been explored in Australia.

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 can result in reduced yields and difficult harvest. Plant growth regulators have been around for many years but results can be variable, even having negative effects on yield. The Irrigated Cropping Council (ICC) conducted trials in 2003 and 2004 that saw some reduction in lodging but little yield response. At the same time, trials on nitrogen management in cereals demonstrated that to achieve high yields, crops do not necessarily need heavy sowing rates and large amounts of nitrogen at sowing, with corresponding lush crop in early season prone to lodging. This has seen many growers adopt a topdressing strategy 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 yielding eight t/ha.

A trial conducted at the ICC trial block in 2012 which aimed to grow 10 t/ha of wheat and barley was deliberately sown heavy 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.

Plant growth regulator (PGR) is a term that describes many agricultural and horticultural chemicals that influence plant growth and development. This influence can be positive; e.g. larger fruit or more pasture growth, or negative; e.g. shorter stems or smaller plant canopies. This paper/presentation will focus on the PGRs that 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 they are applied with the intention of reducing excessive growth in irrigated broadacre crops. Currently, there are four broad groups of PGRs in use in Australian crops. The four broad groups of PGRs are as follows:

1. Ethephon; e.g. Ethrel®.
  - ii. Onium types; e.g. Cycocel®, Pix® (*n.b. Pix® is registered only for cotton*).
  - iii. Triazoles; e.g. propiconazole (*n.b. propiconazole is registered as a fungicide not a PGR*)

<sup>5</sup> Jessop RS, Fittler M. (2009). Triticale production Manual – an aid to improved triticale production and utilisation. [http://www.apri.com.au/1A-102\\_Final\\_Research\\_Report.pdf](http://www.apri.com.au/1A-102_Final_Research_Report.pdf)

## MORE INFORMATION

[Plant growth regulators](#)

[Plant growth regulators in broad acre crops](#)

[PGRs and their agronomic and economic benefits to high yield potential cereal, pulse and oilseed crops](#)

[Good things come in small packages: plant growth regulators in barley](#)

[Mixed bag – dual purpose crops, PGRs and other local research – TAS.](#)

1. Trinexapac-ethyl; e.g. Moddus®, Moddus Evo (n.b. Moddus® is registered for ryegrass seed crops, poppies and sugar cane. Moddus Evo is an enhanced dispersion concentrate of Moddus, it is not currently registered but has been submitted to the APVMA for registration in Australian cereals)

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

The majority of the PGRs (groups ii to iv) reduce crop height by reducing the effect of the plant hormone; gibberellin. These are applied at early stem elongation (Z30-32).

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

Other benefits claimed by the producers of the various products include:

1. Better root development that allows for increased root anchorage.
2. Better root development providing greater opportunity for water and nutrient scavenging.
3. May offer improved grain quality.
4. Reduction in shedding in barley.
5. Increased Harvest Index (the ratio between grain and total dry matter).
6. Faster harvest speeds and reduced stress at harvest.

An alternative to the chemical PGRs is grazing. Demonstrated in the Grain and Graze project on a number of sites was the effect grazing had on the crops where the grazed treatments were regularly shorter than the non-grazed treatments and were less prone to lodging.

### Conclusions

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

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

The yield improvements seen in barley in the ICC trials need further investigation as the reason behind the increase is not clear.<sup>6</sup>

In Australia, the range of PGR's available to growers is limited to chlormequat chloride (wheat only) and ethephon (barley only) and the use of these products has generally been relatively low. The principle reason for this is simply that responses are viewed as variable and growers have not regularly seen the benefit of incorporating them into their management programs.

A combination of trinexapac-ethyl# and chlormequat# applied at GS31 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.<sup>7</sup> Overseas, chlormequat chloride has been found to inhibit gibberellin production and has been recommended in triticale, rye, wheat, oats, and winter barley.<sup>8</sup>

### Moddus Evo

Key points:

- Moddus Evo reduces lodging and can increase yields

<sup>6</sup> Jones D. (2014). GRDC Update Papers: Plant Growth Regulators. <https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Plant-growth-regulators>

<sup>7</sup> Long W. (2005). GRDC Final reports: AC0003 – Plant growth regulators and their agronomic and economic benefits to high yield potential cereal, pulse and oilseed crops. <http://finalreports.grdc.com.au/ACC0003>

<sup>8</sup> BASF. How do PGR's work? [http://www.agricentre.basf.co.uk/agroportal/uk/en/crop\\_solutions/cereals\\_5/lodging\\_canopy\\_management/canopy\\_management\\_in\\_cereals.html](http://www.agricentre.basf.co.uk/agroportal/uk/en/crop_solutions/cereals_5/lodging_canopy_management/canopy_management_in_cereals.html)

- Application timing and concentration of Moddus Evo is critical
- Moddus Evo should not be applied to plants under stress
- Moddus Evo has improved formulation stability and plant uptake

Lodging is considered one of the biggest barriers to reliably achieving high yields in intensive cereal production in Australia. 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 range of overseas countries including New Zealand, UK and Germany to reduce the incidence and severity of lodging and optimise the yield and quality of high yielding wheat, barley and oat crops. Moddus® Evo is an enhanced dispersion concentrate (DC) formulation 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 submitted to the APVMA for registration in Australian cereals.

The purpose of this research was to investigate the value of Moddus applications to Australian cereals to reduce lodging and improve yields.

#### Methods

Field trials were run across Australia from 2004 to 2011. A range of varieties, climatic conditions and geographical locations were used. Trials were established as small plots, typically 20-120m<sup>2</sup> using a randomised complete block design, incorporating 3 to 6 replicates.

Measurements were taken of the effect of Moddus application on plant growth, stem strength, stem wall thickness, lodging, lodging score, yield, as well as grain quality measurements.

#### Results

Overall improvements in yield were often correlated with a reduction in stem height irrespective of whether lodging occurred or not. 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 there were a few trials with anomalous results, where Moddus® Evo application did not improve yield. When these trials were examined it was found that either environmental conditions during the lead up to the Moddus® Evo application were poor, with either extensive frosting, drought, poor subsoil moisture profile or nutrient deficiencies within the crop. As a result Moddus® Evo should only be applied to healthy growing crops with optimum yield potential.

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. The timing and concentration of Moddus® Evo applications is critical to produce the optimal yield improvements. Moddus® should only be applied to healthy growing crops. Moddus® Evo is a new generation plant growth regulator offering improved yield potential to Australian cereals.

#### MORE INFORMATION

[Moddus Evo: Controlling plant growth for reduced lodging and improved cereal yields.](#)

## 10.2 Canopy management

Key points:

- canopy management starts at seeding: sowing date, variety, plant population and row spacing are fundamental. It is more than purely delaying nitrogen.
- correct identification of the key growth stages for input application is essential, particularly during early stem elongation when the key leaves of the crop canopy emerge.

- Knowledge of soil moisture status and soil nitrogen reserve and supply need to be taken into account in order to match canopy size to environment.
- crop models can help integrate crop development, environmental conditions and nutrient status in order to make better canopy management decisions.<sup>9</sup>

### What is canopy management?

The concept of canopy management has been primarily developed in Europe and New Zealand – both distinct production environments to those typically found in most grain producing regions of Australia.

Canopy management includes a range of crop management tools to manage crop growth and development to maintain canopy size and duration to optimise photosynthetic capacity and grain production (Photo 2). One of the main tools for growers to manage the crop canopy is the rate and timing of applied fertiliser N. The main difference between canopy management and previous N topdressing research is that all or part of the N inputs are tactically delayed until later in the growing season. This delay tends to reduce early crop canopy size but this canopy is maintained for longer, as measured by green leaf retention, during the grain filling period.<sup>10</sup>



**Photo 2:** Examples of controlled canopy cover. Thinner crop canopy (left) yield = 6.18 t/ha and 12% protein and thicker crop canopy (right) yield = 6.20 t/ha and 10.6% protein. Kellalac wheat sown 11th June Gnarwarre (Geelong region), Victoria (in high rainfall zone) region treated with same level of nitrogen.

Source: GRDC

Adopting canopy management principles and avoiding excessively vegetative crops may enable growers to ensure a better match of canopy size with yield potential as defined by the water available.

Canopy management includes a range of crop-management tools for crop growth and development, to maintain canopy size and duration and thereby optimise photosynthetic capacity and grain production. Other than sowing date, plant population is the first point at which the grower can influence the size and duration of the crop canopy<sup>11</sup> and one of the main tools for growers to manage the crop canopy 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.

9 GRDC. (2009). Canopy management factsheet. [https://grdc.com.au/\\_data/assets/pdf\\_file/0014/202523/canopy-management.pdf.pdf](https://grdc.com.au/_data/assets/pdf_file/0014/202523/canopy-management.pdf.pdf)  
 10 McMullen G. (2009). Canopy management in the Northern grains region – the research view. NSW DPI. <http://www.nqa.org.au/results-and-publications/download/31/australian-grain-articles/general-1/canopy-management-tactical-nitrogen-in-winter-cereals-july-2009-.pdf>  
 11 <https://www.researchgate.net/file.PostFileLoader.html?id=5780fa6bf7b67e860b4def31&assetKey=AS%3A381929540079624%401468070506798>

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FEEDBACK

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. The extreme of this scenario of excessive early growth is haying-off, where 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 not enough stored water-soluble carbohydrates to fill the grain. Therefore, grain size and yield decrease.

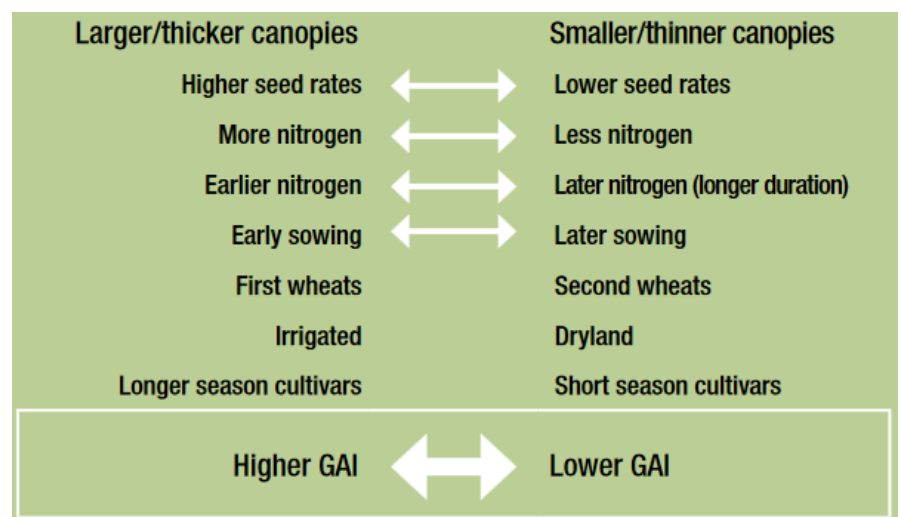
To attain maximum yield, it is important to achieve a balance between biomass and resources. The main factors that can be managed are:

- plant population
- row spacing
- inputs of N
- 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.<sup>12</sup>

Applying nitrogen (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.

However, canopy management is not about a delayed N strategy but starts at seeding by determining the correct plant establishment for the chosen seeding date and row spacing. This must also take into account available soil moisture and nutrients (Figure 1).<sup>13</sup>



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

Source: GRDC

<sup>12</sup> N Fettell, P Bowden, T McNee, N Border (2010) Barley growth & development. PROCROP Series. Industry & Investment NSW/ NSW Department of Primary Industries. [http://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0003/516180/Procrop-barley-growth-and-development.pdf](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/516180/Procrop-barley-growth-and-development.pdf)

<sup>13</sup> GRDC. (2009). Canopy management Factsheet. [https://grdc.com.au/\\_data/assets/pdf\\_file/0014/202523/canopy-management.pdf.pdf](https://grdc.com.au/_data/assets/pdf_file/0014/202523/canopy-management.pdf.pdf)

While N timing and rate are key components of successful canopy management, it is essential that they are considered in conjunction with the inter-related factors of:

- soil moisture;
- soil nitrogen reserves;
- seeding date; and
- 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.

### 10.2.1 Canopy management in WA

A well-managed canopy has an optimal number of tillers (providing green leaf area) for any given season so that moisture is conserved for efficient grain-fill.

Canopy management trials near Wagin, Western Australia, indicate medium plant density (120 plants per square metre) and tactical nitrogen applications during the growing season can pay off with higher yields – especially in years with a drier-than-average finish.

Yields can be compromised if plant density is too high (180 plants/m<sup>2</sup>) and if too much nitrogen is applied at seeding.

Trial sites were set up from 2011 to 2013 at east Wagin, Kulin, Kellerberrin and Kojonup to investigate canopy management parameters for WA cropping regions. At each site, researchers monitored how wheat canopy density affected grain yield and quality and the level of disease and frost damage.

Yield results from 2011 and 2012 were similar for all plant densities and time of nitrogen application across all treatments at the Kulin, Kellerberrin and Kojonup sites, despite very different rainfall patterns in those years, ranging from decile 6–7 to decile 1–2. The yield results were a reflection of the seasonal conditions and the wheat plant's ability to adjust when it is stressed.

However, at the Wagin trial, researchers were able to measure yield responses to seeding rates of 35, 55 and 80 kilograms per hectare and a standard 40 kg/ha of nitrogen applied either all up-front, split at seeding and GS31, or split at seeding, GS14 and GS31.

#### *Findings from the Wagin site in 2012 included:*

- the lowest yield of 1.82 t/ha occurred when all nitrogen was applied up-front, combined with a high plant density (180 plants/m<sup>2</sup>). These two factors reduced yields significantly (by up to 0.5 t/ha) because the canopy outgrew its yield potential and there was insufficient stored moisture available for grain fill;
- medium seeding rates (plant density of 120 plants/m<sup>2</sup>) and split nitrogen produced reliable yields of about 2.33 t/ha;
- the highest yields (2.38 t/ha and 2.23 t/ha) were achieved at low (plant density of 75 plants/m<sup>2</sup>) or medium seeding rates and all nitrogen applied up-front;
- crops could reach yield potential using high seeding rate and delayed nitrogen application; and
- ryegrass biomass fell as seeding rate increased.

Yield losses of up to 1 t/ha can occur if in-crop rainfall does not support crops sown at high seeding rates and supplied with the full rate of nitrogen at seeding.

In the Wagin environment, in a low-to-average-rainfall year, growers can target medium sowing rates and be more flexible in applying nitrogen to play the season as it unfolds – without affecting yield.

Restricting canopy growth can conserve soil moisture, reduce disease pressure and allow crops to finish better. Split nitrogen application is a good risk mitigation



strategy, especially if the long-term forecast is not promising or if subsoil moisture levels are low.<sup>14</sup>

### 10.2.2 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 tonnes per hectare).
2. Adjust canopy management based on paddock nutrition, history and seeding time to achieve target head density.
3. Established plant populations for wheat of between 80 and 200 plants/m<sup>2</sup> would cover most scenarios.
4. Lower end of range (80–100 plants/m<sup>2</sup>) – earlier sowings/high fertility and or low yield potential low-rainfall environments.
5. Higher end of the range (150–200 plants/m<sup>2</sup>) – 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:
  - » maximise potential grain size and grain number per head;
  - » maximise transpiration efficiency;
  - » ensure complete radiation interception from when the flag leaf has emerged (GS39); and
  - » keep the canopy green for as long as possible following anthesis.

Keeping tiller number just high enough to achieve potential yield will help preserve water for filling grain and increase the proportion of WSCs. The timing of the applied N during GS30–33 window can be adjusted to take account of target head number; earlier applications in the window (GS30) and can be employed where tiller numbers and soil nitrogen seems deficient for desired head number. 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 less tillers surviving to produce a head. Much of the research on topdressing nitrogen (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 conditions. In these situations, research has shown that positive responses can be achieved, especially when good rainfall is received after N application.<sup>15</sup>

### 10.2.3 Setting up the canopy

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

Boosting tiller numbers with seeding nitrogen results in greater tiller loss between stem elongation and grain fill. This specifically occurs in two situations: low rainfall, short environments and when soil moisture is limited. In these situations moisture and nutrient resources are used prior to stem elongation to produce biomass, which fails to contribute to grain yield. Indeed by 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.

<sup>14</sup> GRDC, (2015). Hot topics: Canopy management in western region. <https://grdc.com.au/Media-Centre/Hot-Topics/Canopy-management-in-western-region/Details>

<sup>15</sup> GRDC (2014). Advancing the management of crop canopies. <https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/qc105-canopymanagement>

### 10.2.4 Soil moisture status

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

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

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.

By setting up a smaller crop canopy, modelling demonstrates that limited stored soil moisture can be reserved for use at grain fill, rather than being depleted by excessive early growth. However, in higher rainfall regions and in a good season setting-up a small canopy may result in actual yield 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® and the Sirius Wheat Calculator (developed in New Zealand) offer simple tools to record and assess multiple options about the relationship between growing plants and the environment including available water and nutrients.

### 10.2.5 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.

Timing of deep-soil tests is important. Deep-soil nitrogen tests carried out in summer, several months before seeding may reveal less soil nitrogen than tests carried out after the autumn rain, 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 5).<sup>16</sup>



**Photo 3:** A 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). 443 tiller/m<sup>2</sup> – N-rich (left) and 266 tillers/m<sup>2</sup> (right).

Source: GRDC

<sup>16</sup> GRDC. (2009). Canopy management Factsheet. [https://grdc.com.au/\\_data/assets/pdf\\_file/0014/202523/canopy-management.pdf](https://grdc.com.au/_data/assets/pdf_file/0014/202523/canopy-management.pdf)

A useful guide that requires no sophisticated equipment is to apply an excess of nitrogen at sowing, for example 50 to 100 kg N/ha, to a small area of the paddock, approximately 2m by 10m.

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 is directly registering soil N supply, rather than 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. This canopy sensing can be done remotely from aircraft/satellites or with a hand-held or vehicle mounted sensor.

### 10.2.6 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.

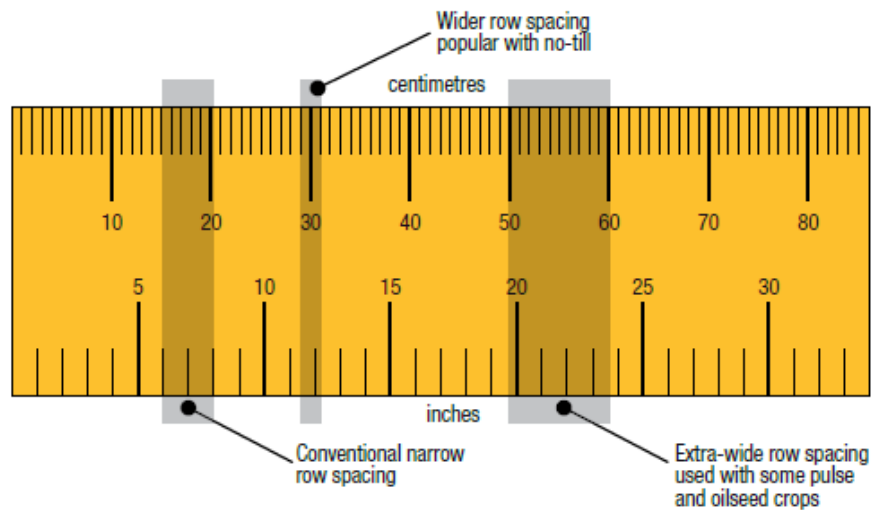
Overall, earlier planting provides greater opportunities to manipulate the crop canopy during the stem elongation period: the plant's development periods are extended along with the earlier tillering period.

### Row spacing

Key points:

- Increased interest in no-till farming has created a trend for wider crop row spacing (Figure 2).
- In general, increasing row spacing up to 50 cm has minimal effect on cereal yield when yield potential is less than 2 tonnes per hectare.
- In higher rainfall areas, where cereal crops have higher potential yields, significant yield decreases have been recorded with wider row spacing (greater than 25 cm).
- The yields of broadleaf crops vary in their response to wider row spacing.
- Precision agriculture allows for easier inter-row sowing and fertiliser applications at wider row spacing.<sup>17</sup>

<sup>17</sup> GRDC. (2011). Crop placement and row spacing factsheet – Southern region. <https://grdc.com.au/resources-and-publications/all-publications/factsheets/2011/02/crop-placement-and-row-spacing-southern-fact-sheet>



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

Source: GRDC

### Yield

- There are a number of reasons why growers might wish to pursue wider row spacing in cereals, for example, residue flow, inter-row weed and disease control. However, in all project trials (2007–10) on wheat covering a wide range of rainfall scenarios, increasing row width reduced yield.
- The yield reduction in wheat was particularly significant when row width exceeded 30 cm.
- Crop row spacing is an important factor for weed competition (Photo 4).
- At row widths of 30 cm the reduction in wheat yield compared to narrower 20–22.5 cm row spacing was dependent on overall yield potential.
- At yields of 2–3 tonnes per hectare the yield reduction was negligible.
- At yields of 5 t/ha the yield reduction was between 5–7%, averaging about 6%.
- Data from a single site suggests that rotation position may influence the yield response in wider row spacing in wheat. In wheat, wheat-on-wheat suffered less yield reduction with wider rows than an equivalent trial at the same site which was in wheat after canola.<sup>18</sup>



**Photo 4:** 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.

Source: [Weedsmart](#)

<sup>18</sup> GRDC. (2014). Advancing the management of crop canopies. <https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/qc105-canopymanagement>

### 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 indicates that increasing seeding rates such 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 increase weed germination and moisture loss through greater soil disturbance.<sup>19</sup>

### Dry Matter

- Wider row (30 cm and over) spacing reduced harvest dry matter relative to narrower rows (22.5 cm and under), with differences growing steadily (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.<sup>20</sup>

### 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.<sup>21</sup>

### Nitrogen management

Nitrogen management has not been found to interact with row spacing, 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 stem elongation applied nitrogen was more important with narrow row spacing since higher yields lead to a tendency for lower protein.<sup>22</sup>

#### 10.2.7 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 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 exact growth stage. While GS31 should be the target growth stage for in-crop N application, the window can be expanded from GS25 to 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).

Figure 3 presents the results from winter wheat cropping trials across Australia on the use of in-crop solid nitrogen at stem elongation. This shows that where soil nitrogen

19 GRDC. (2014). Advancing the management of crop canopies. <https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/qc105-canopymanagement>

20 GRDC. (2014). Advancing the management of crop canopies. <https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/qc105-canopymanagement>

21 GRDC. (2014). Advancing the management of crop canopies. <https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/qc105-canopymanagement>

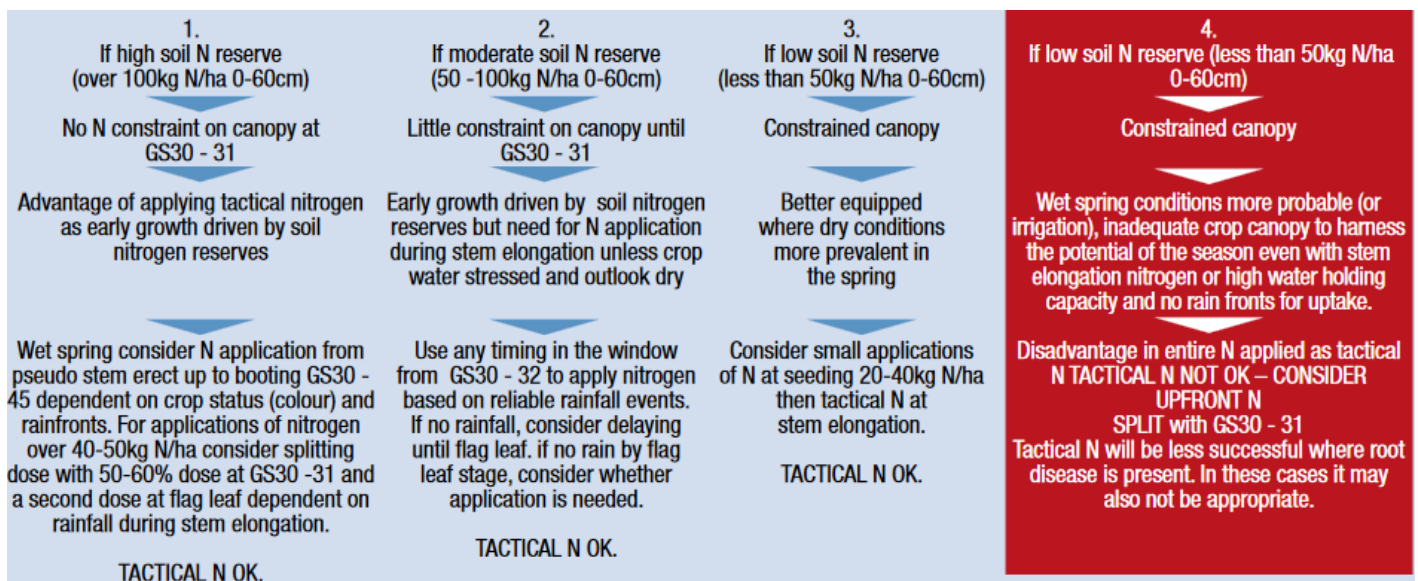
22 GRDC. (2014). Advancing the management of crop canopies. <https://grdc.com.au/resources-and-publications/all-publications/publications/2014/01/qc105-canopymanagement>

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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) has limited the results produced from trials. These trials assessed stem elongation N use in cereals grown on wider-row spacings 300 to 350 mm compared to 175 to 200 mm. 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 six per cent in the HRZ.<sup>23</sup>



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

Source: GRDC

### 10.2.8 Limitations of tactical nitrogen application

The main limitation to tactical N application is the ability to reliably apply N before a rain event, 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.

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.

Based on sound trials and paddock experience, the aim of improving the economic outcome at the end of the season through manipulation of the most costly input is taking shape. Adoption of these techniques would be further aided by development of efficient, in-soil N-application equipment.

#### MORE INFORMATION

[Canopy management factsheet](#)

[Cereal growth stages guide](#)

[Advancing the management of crop canopies.](#)

<sup>23</sup> GRDC. (2009). Canopy management Factsheet. <https://grdc.com.au/resources-and-publications/all-publications/factsheets/2010/02/canopy-management>