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GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

BARLEY

SECTION 10

PLANT GROWTH REGULATORS AND CANOPY MANAGEMENT

CANOPY MANAGEMENT | KEY STAGES FOR DISEASE CONTROL AND CANOPY MANAGEMENT | USE OF PLANT GROWTH REGULATORS

SECTION 10

Plant growth regulators and canopy management

10.1 Canopy management

In the past, much of the research on topdressing nitrogen (N) in northern New South Wales (NSW) 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 good responses can be achieved, especially when good rainfall is received after N application (*Australian Grain*, July/August 2007). Recently, though, there has been significant interest in the role of canopy-management principles for crop production in the northern grains region. [1]

Canopy management is managing the green surface area of the crop canopy in order to optimise crop yield and inputs. It is based on the premise that the crop's canopy size and duration determines the crop's photosynthetic capacity and therefore its overall grain productivity.

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. Other than sowing date, plant population is the first point at which the grower can influence the size and duration of the crop canopy. [2]

The concept of canopy management has been primarily developed in Europe and New Zealand—both different production environments from those typically found in most grain-producing regions of Australia, especially the northern grains region.

Canopy management includes a range of tools to manage crop growth and development in order to maintain canopy size and duration and thereby optimise photosynthetic capacity and grain production. 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 input is 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.

So, can it work under Australian conditions, especially in the shorter growing season of northern NSW? Results from southern regions have certainly showed some potential especially in areas with high yield potential and therefore higher N inputs, but further research was required to test and validate the principles in northern NSW. [3]

1 G McMullen (2009) Canopy management in the northern grains region—the research view. Northern Grains Alliance, July 2009, 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 GRDC (2005) Cereal growth stages. Grains Research and Development Corporation Sept. 2005, http://www.grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf

3 G McMullen (2009) Canopy management in the northern grains region—the research view. Northern Grains Alliance, July 2009, 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

10.1.1 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^2 would cover most scenarios.
4. Lower end of range (80–100 plants/m^2) – earlier sowings/high fertility and or low yield potential low-rainfall environments.
5. Higher end of the range (150–200 plants/m^2) – 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.[4]

10.1.2 The importance of canopy management

Since N application at stem elongation is associated with higher protein levels, growers of malting barley need to be aware that whilst delayed N timing can be useful in barley, higher protein content may need to be countered with lower total N doses if a greater proportion of N application is moved from seedbed to stem elongation. [5]

If the canopy becomes too big it competes with the growing heads for resources, especially during the critical 30-day period before flowering. This period is important, as it 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 grain-fill.

After flowering, temperature and evaporative demand increase rapidly. If there is not enough soil moisture, the canopy dies faster than the grain develops, leading to the production of small grain.

Excessive N and high seeding rates are the main causes of excessive vegetative production. Unfortunately, optimum N and seeding rates are seasonally dependent. Under drought conditions, N and seeding rates regarded as inadequately low under normal conditions may maximise yield, whereas higher input rates may result in progressively lower yields. Alternatively, in years that are wetter than normal, yield may be compromised with normal input rates. The extreme of this excessive early growth scenario is haying-off, where a large amount of biomass is produced, using a lot of

More information

http://www.grdc.com.au/Resources/Publications/2014/01/Advancing-the-management-of-crop-canopies

4 GRDC (2014), Advancing the management of crop canopies. http://www.grdc.com.au/CanopyManagementGuide

5 GRDC (2005) Cereal growth stages. Grains Research and Development Corporation Sept. 2005, http://www.grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf

water and resources. 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

Of these factors, N, row spacing and plant population are the most important to canopy management. Excessive amounts of N and high plant density can result in greater early growth, leaving less water for the grain-filling period. This may result in lower grain retention as N or seeding rates are increased. [6]

10.1.3 Grazing cereal crops as a management tool

Well-managed, dual-purpose cereals provide producers with an opportunity for increased profitability and flexibility in mixed farming systems by enabling increased winter stocking rates and generating income from forage and grain. Typically, these crops are earlier sown, longer season varieties that provide greater dry matter production for grazing. Barley's vigorous early growth generally produces more dry matter for grazing and greater grain yield compared with grazed wheat. Research has shown that to avoid grain-yield penalties, stock must be removed from cereals before the end of tillering (GS30). However, the timing and intensity of grazing during the season can incur yield penalties, particularly when grazing pressure is high and late in the grazing period.

Grazing can sometimes be beneficial to grain production by reducing lodging; in seasons with dry springs, grazing can increase grain yields due to reduced water use in the vegetative stages, leaving more soil water for grain-fill. The challenge for growers is to find the balance of optimising dry matter (DM) removal without compromising grain production.

NSW Department of Primary Industry (DPI) trials conducted at Tamworth from 2007 to 2010 focused on management strategies that could be used to manipulate the balance between DM removal and grain production. The 2007 grazing trial compared the performance of eight barley varieties that were planted either early (May 11) or during the main sowing window (June 25). The 2009 grazing trial investigated the interaction between three barley varieties—Urambie⯑, Commander⯑ and Fitzroy⯑) and plant populations of 100 and 200 plants/m^2. In 2010, Commander⯑ and the experimental VB0611 barley were grazed early (at GS25), late (at GS30) or both early and late. All trials were overlaid with plus or minus grazing treatments where grazing was simulated with the use of a slasher.

The trail found that to maximise the accumulation of biomass for winter grazing, it was important to ensure that cereal crops intended for grazing were sown early (April to the first week of May). Sowing early in the 2007 grazing trial resulted in significantly greater DM yields at GS30 and grain yield for all barley varieties. On average, there was a 40% greater DM production for the early plant compared with the main-season plant. Similarly, there was an average 1.59 t/ha ($P < 0.05$) grain-yield penalty across barley varieties for delaying sowing from the early to the main sowing season. The severe grain-yield penalty observed from grazing main-season-planted cereals is associated with grazing delaying maturity, which meant flowering occurred later when conditions were hotter and drier. In the 2007 trial, grazing delayed flowering of barley by 6–11 days, depending on variety.

[6] NSW Industry & Investment (2010) Procrop barley growth & development. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/516180/Procrop-barley-growth-and-development.pdf

Manipulating plant population is a simple management option that can have a significant impact on DM production for grazing and grain yield. Increasing plant populations from 100 to 200 plants/m² (doubling sowing rate from 60 to 120 kg/ha) for the barley varieties Fitzroy(b, Urambie(b and Commander(b significantly ($P < 0.05$) increased DM yield by 710, 335 and 407 kg DM/ha, respectively (Figure 1). Two DM cuts could be taken from Fitzroy(b and Urambie(b treatments, compared with only one from the Commander(b treatment, which produced approximately half the DM biomass. Increasing plant population significantly ($P < 0.05$) increased grain yield for Fitzroy(b and Commander(b by 0.36 and 0.44 t/ha, respectively, when no grazing was implemented. Under grazing treatments, Urambie(b was the only variety to have a higher yield (0.33 t/ha) at the higher plant population. At 200 plants/m², grazing significantly reduced the grain yield of all varieties, whereas, at 100 plants/m², a grain yield penalty was observed only for Urambie(b. Therefore, using higher plant populations to increase DM yield for grazing is achievable but for increasing grain yield may be less reliable.

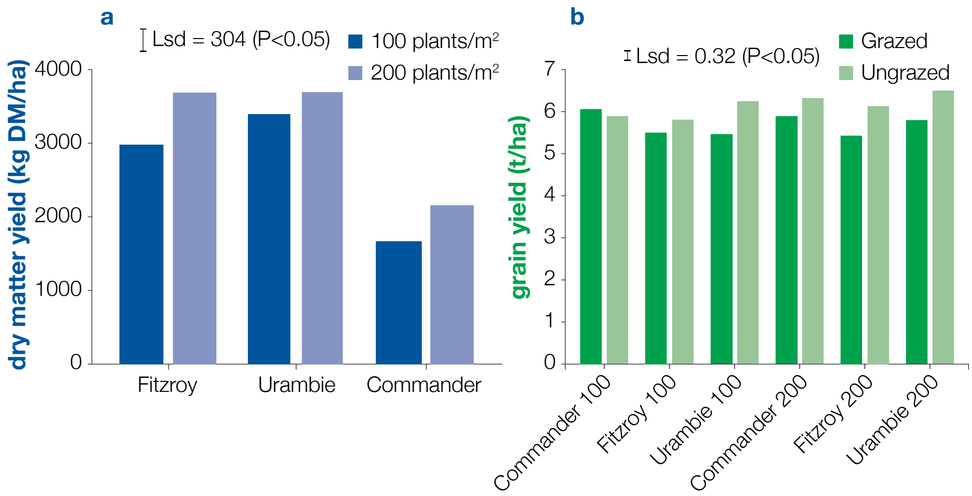

Figure 1: (a) Dry matter yield for grazing from three barley varieties at either 100 or 200 plants/m², and (b) grain yield for three barley varieties grown at 100 or 200 plants/m² and either grazed or ungrazed.

Grazing can be used to limit early canopy growth and therefore is a management tool to reduce the incidence of lodging. Lodging remains a significant problem in barley and has been estimated to cause yield losses of up to 40%. In the 2010 grazing trial, it was observed that grazing late had the greatest potential to reduce lodging scores, particularly in the two barley varieties (Commander(b and the experimental VB0611). The early + late grazing system reduced lodging to a similar extent to late grazing, whereas early grazing reduced the lodging scores only slightly. These results are directly related to the quantity of DM removed (Figure 2).

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/03/Grazing-wheat-and-barley-impacts-on-crop-canopy-management-lodging-and-grain-yield#sthash.63vKKWmW.dpuf

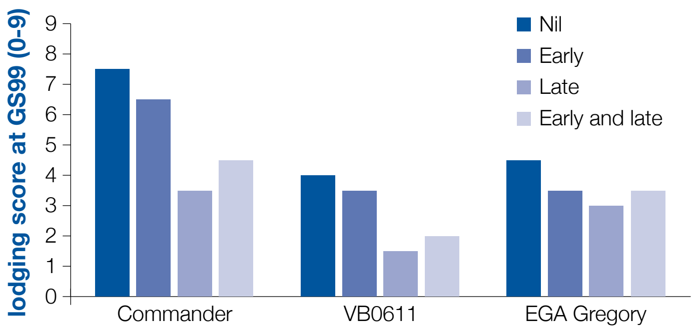

Figure 2: Influence of ungrazed, early, late and early + late grazing systems on lodging scores (0, standing; 9, flat).

10.1.4 Research on the Liverpool Plains

Since 2006 a collaborative research group including NSW DPI, Northern Grower Alliance (NGA), AgVance Farming, and Nick Poole from the Foundation for Arable Research (FAR), New Zealand, has conducted trials. This work, funded by GRDC, has focused on the effect of delayed N applications in high-yielding crops on the Liverpool Plains.

Further research by NSW DPI and NGA also assessed the role of different N fertilisers and measuring the losses of N due to volatilisation. [7]

The laboratory-based work has verified that the presence of calcium carbonates at the soil surface significantly increases the potential losses of N; however, some N fertiliser products can reduce the potential losses (e.g. urea ammonium nitrate liquid, liquid ammonium nitrate and urea treated with a urease inhibitor—GreenUrea®). Field-based estimates of volatilised N are to commence in the coming spring under a GRDC-funded project. [8]

Summary

Results from 3 years of supplementary irrigated research provide important pointers for the use of canopy-management principles in northern NSW. Tactically delaying N is a management system that allows flexibility to respond to seasonal conditions and manage climate variability. Research has shown that N fertiliser could 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, which are very responsive to high N-fertiliser inputs.

Further research in 2009 repeated these impressive responses. Along with these primary aims, the research group is also looking at using crop reflectance to assist in making N fertiliser decisions. To date, crop reflectance (measured as normalised difference vegetation index, NDVI) measurements at key growth stages have shown strong relationships to crop structure and yield. [9]

10.1.5 The commercial view

The results of three years of trials carried out by AgVance Farming, NSW DPI, NGA and Nick Poole (FAR, New Zealand) led to the following conclusions.

Yield was maximised in the treatments where all of the N was applied up-front, or split 50–50 (between planting and GS30–31). In one trial last season, NSW DPI/NGA demonstrated that this might not be the case for longer season varieties, but this needs to be proven over a number of years.

Generally, a full profile of moisture receives sufficient N initially to provide the entire crop requirement to the predicted yield level. If yield potential is higher due to favourable seasonal conditions, there is generally opportunity to apply small amounts of N later to increase yield as the season progresses, but usually this is not necessary.

In a situation of lower moisture profile, N can be applied at a rate less than the target-yield level requirement and topped up later in front of rainfall, as opportunities present. This requires careful planning and preparation on the grower's behalf, in order to take advantage of impending rainfall, sometimes in short timeframes.

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[7] G McMullen (2009) Canopy management in the northern grains region—the research view. Northern Grains Alliance, July 2009, 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.

[8] G McMullen (2009) Canopy management in the northern grains region—the research view. Northern Grains Alliance, July 2009, 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

[9] G McMullen (2009) Canopy management in the northern grains region—the research view. Northern Grains Alliance, July 2009, 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

The 50–50 split application of N extends the period that N can be applied through the season without the 'cliff-face' drop in yield if N is not applied at precisely GS30–31. Effectively it improves the margin of error available to the grower if rainfall is not forthcoming at GS30–31.

Where growers are set up for, and using, precision agriculture, a 70–30 approach can be taken when there is a full soil moisture profile, and a 50–50 approach when soil moisture is likely to be limiting. This is where a proportion of the predicted N requirement is held back until after NDVI imaging has taken place, and N is then applied based on NDVI results. This also requires a high level of grower organisation and planning.

More information

http://www.grdc.com.au/ApplyingPA

Limitations of tactical nitrogen application

The main limitation to such practices in the north is the ability to reliably apply N before a rain event, to enable roots to access soluble N in the root-zone.

An analysis of rainfall events comparing Clare (South Australia) and Wagga Wagga (southern NSW) with Quirindi, (North West Slopes of NSW) showed that Quirindi had only 30% of the opportunities to apply N that the southern locations had, and that the predictability of rainfall events >3 days before rain was unreliable.

Predicted rain fronts may pass without yielding a single drop, therefore, applying N throughout the season is risky. Predicting rain events becomes increasingly difficult heading north and west of the Liverpool Plains, e.g. Moree and Walgett.

Foliar N application has gained popularity in recent years; however, this is only suitable for relatively low rates of N addition. In the likelihood of higher N input requirement, a system to apply N into the wet soil profile, after a rainfall event, at efficiencies that are economic needs to be devised.

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

While traditional ideas of canopy management are based on southern experiences, northern region growers and agronomists are developing their own guidelines for the northern cropping zone. Based on trial work and in-paddock experiences, 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 throughout the northern cropping zone would be further aided by development of efficient, in-soil N application equipment. [10]

10.2 Key stages for disease control and canopy management

The optimum timing for foliar-applied fungicides in cereals is from the start of stem elongation to ear emergence (GS30–59). In barley, the second last leaf formed is the key leaf. This is the leaf below the flag and is termed flag minus 1 (flag-1). This leaf appears at approximately the third node stage (GS33). This period coincides with the emergence of the four most important leaves in the crop and the ear. The optimum time for spraying a fungicide to protect a leaf is at the point of full emergence. Leaves unemerged at the time of application will not be properly protected. Leaves will usually be free from foliar disease on emergence. The time between when the disease spores land on the leaf and when an infection point is visible is called the latent period or latent phase.

This period is temperature-driven and differs between diseases. It can be as short as seven days for diseases such as powdery mildew. [11]

[10] P McKenzie (2009) Canopy management in the Northern Grains region—the commercial view. Northern Grains Alliance, July 2009, 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

[11] GRDC (2005) Cereal growth stages. Grains Research and Development Corporation Sept. 2005, http://www.grdc.com.au/uploads/documents/GRDC%20Cereal%20Growth%20Stages%20Guide1.pdf

Five to 10 years ago, it would be common to make decisions on fungicide applications for foliar disease based on thresholds of infection. These thresholds varied from 1 to 5% of plants infected. The problem that soon became apparent to growers and advisers was that in the paddock it was difficult to calculate when this disease threshold had been reached, not least because of the sporadic nature of the initial foci of the disease. In addition, by the time growers realised the threshold had been reached and the spray operation had been carried out, the crops were badly infected. When crops that are badly infected with stripe rust are treated with fungicides, the control experienced is poor, since fungicides work better as protectants than as curatives.

Because its flag leaf is less important, barley is far more difficult than wheat to pinpoint an optimal timing window for fungicide application. In addition, most of the popular varieties such as Gairdner⫯ have some disease weaknesses. Therefore, the advice is to monitor from late tillering (GS25) for the presence of disease on the older leaves. Consider application based on propiconazole (Tilt, Bumper) where net blotch and/or scald are evident on newer leaves at GS30, or triadimefon (Triad/Bayleton) for mildew.

Barley requires careful monitoring, and its lower leaves, which emerge earlier than in wheat, are more important to the plant than the lower leaves in wheat. Other points to consider when using fungicide in barley canopy management are:

- The flag leaf is relatively small and unimportant in barley compared with wheat, and its appearance is therefore not a convenient mid-season focal point for strategies.
- Earlier, more important, leaves that require fungicide application create a later season gap in protection, therefore making two sprays more effective in this crop.
- Two-spray programs increase the likelihood of fungicide rate reduction with each spray. In wheat, fungicide activity against rusts is very effective at low rates; however, the existing range of fungicides does not control barley diseases as effectively at equally low rates.
- Barley often suffers from wet-weather diseases early in the season, but then is subject to drier/warmer weather diseases later in the season, again making it more difficult to target a single spray program under diverse disease pressure.

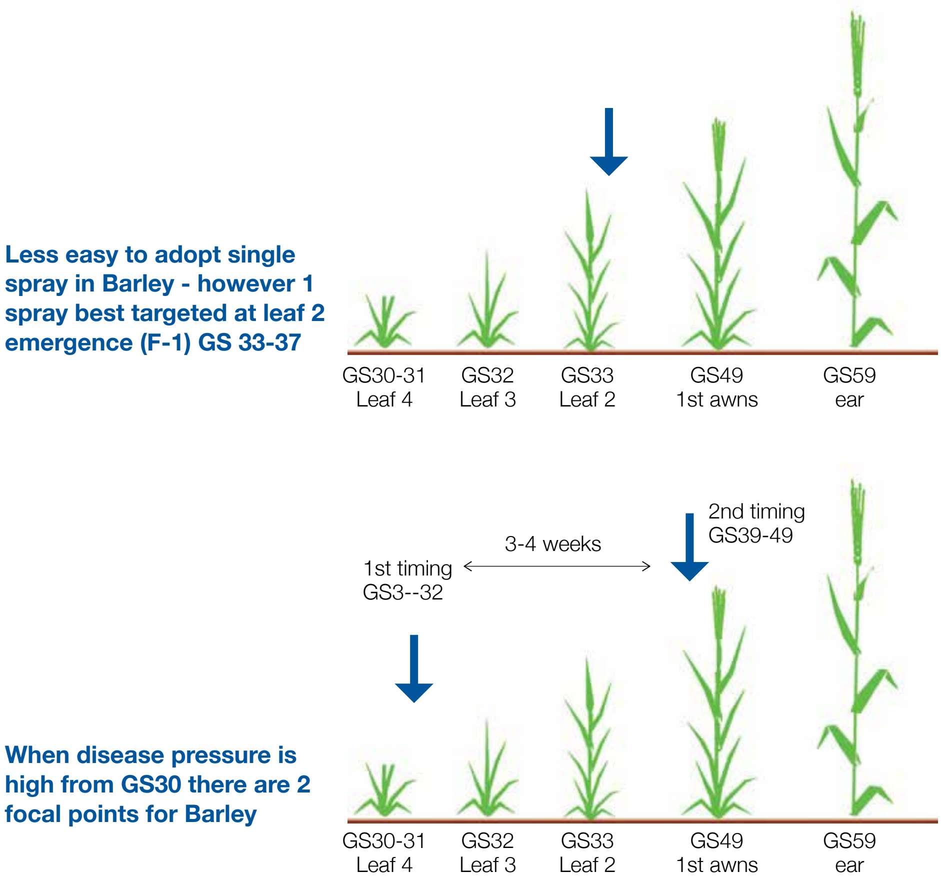

Figure 3: Kay stages for disease control and canopy management

Nick Poole coordinates FAR's GRDC-funded research program in Australia, which focuses on canopy management in cereals. To hear Nick Poole discuss canopy management, visit: http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2009/07/Disease-management-and-crop-canopies.

10.3 Use of plant growth regulators

A tool that may be used to minimise crop lodging and maximise yield, particularly in high-N situations, is plant growth regulators (PGRs). These have been used routinely in high-input, high-yielding cereal systems in Europe and New Zealand for some time to shorten straw height and reduce the incidence of lodging. Lodging causes significant losses in crop production due to reduced movement of water, nutrients and translocation of plant-stored carbohydrates through the stem into the head. Lodging also reduces grain quality and increases harvest losses and the actual cost of the harvesting process. Inhibitors of the plant hormone gibberellin and ethylene producers are the two main PGR groups. Research in Australia to date has been on gibberellin-inhibitor products, which act by blocking gibberellin biosynthesis to reduce internode length in stems, thereby decreasing plant height. There are a number of phases in this pathway, and different PGRs act at different points. For example, chlormequat (Cycocel) acts early in the pathway, whereas more recently developed products such as trinexapac-ethyl (Moddus®) act on later stages.

Plant growth regulators have also been reported to have a yield-enhancement effect by improving the proportion of crop DM that is partitioned into grain yield. This effect has been related to a reduction in the plant resources required for stem elongation, with these resources then available for grain-fill. Some PGRs have also been associated with increased root growth resulting in improved water extraction from soil. Yield responses to

PGRs can be highly variable, with responses ranging from –40% to +2%, depending on product choice, application time, crop or variety and growing season conditions. [12]

In Australia, PGR availability for barley growers is limited to ethephon, and its use has generally been low. The principal reason for this is that responses are viewed as variable and growers have not regularly seen the benefit of incorporating it into their management programs. The key factor contributing to this perception is a lack of appreciation of the conditions and situations where the use of a PGR is appropriate. A great deal of resource has been devoted to optimising crop-husbandry strategies to minimise lodging, but relatively little time has been devoted to identifying the best situations to use PGRs for optimum results. If the field, variety or growing conditions are not conducive to lodging, then the use of a PGR will have no benefit to the grower, and many of the trials undertaken with PGRs have led to conclusions that ignore the fact that a PGR did not need to be applied in the first place. [13]

Moddus (250 g/L of trinexapac-ethyl) is used by cereal growers in a range of countries including New Zealand, the 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 formulation 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 NSW DPI in 2011 and 2012 conducted trails on Moddus to investigate the capacity of PGRs to reduce lodging in Commander⸸ barley, a high-yielding variety with poor straw strength. In both seasons, Commander⸸ and Oxford⸸, a high-yielding variety with good straw strength, were grown at a target plant population of 120 plants/m^2 with four treatments of: nil PGR, Cycocel® (0.2 L/ha), Moddus (1.0 L/ha) and a combination of Cycocel (0.2 L/ha) + Moddus (1.0 L/ha). PGRs were applied in each season during stem elongation (GS31) at a water rate of 100 L/ha. In 2011, sites were established at Tamworth and Spring Ridge, and in 2012, sites were at Moree and Breeza. [14]

NOTE: Moddus is not commercially available and is not currently registered in Australia for these use patterns.

Results from 2011 showed that although the Tamworth site had lower lodging than Spring Ridge, the trends were similar (Table 1). The lodging severity for Commander⸸ was approximately 3 times that observed for Oxford⸸, again highlighting the importance of variety selection in lodging management. The combination of Cycocel and Moddus was the most effective PGR treatment at reducing the severity of lodging compared to the control treatment (nil PGR).

Table 1: Lodging scores (scale 0–9, where 0 is standing and 9 is flat on the ground) at harvest for the Spring Ridge and Tamworth sites in 2011

PGR Treatment	Spring Ridge		Tamworth	
	Commander⸸	Oxford⸸	Commander⸸	Oxford⸸
Nil PGR	7.2	3.0	3.0	1.0
Cycocel	6.2	1.8	2.0	0.2
Moddus	5.3	1.8	2.0	0.0
Cycocel + Moddus	4.6	1.9	1.8	0.0

12 M Gardner, R Brill, G McMullen (2013) A snapshot of wheat and barley agronomic trials in the northern grains region of NSW. GRDC Update Papers, 5 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-snapshot-of-wheat-and-barley-agronomic-trials-in-the-northern-grains-region-of-NSW

13 B. Staines, LM Forsyth and Ken McKee (2013) Moddus Evo: controlling plant growth for reduced lodging and improved cereal yields. GRDC Update Papers 27 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Moddus-Evo-Controlling-plant-growth-for-reduced-lodging-and-improved-yields

14 *M Gardner, R Brill, G McMullen (2013)* A snapshot of wheat and barley agronomic trials in the northern grains region of NSW. GRDC Update Papers 5 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-snapshot-of-wheat-and-barley-agronomic-trials-in-the-northern-grains-region-of-NSW

The ability of PGRs to reduce the severity of lodging appears related to their capacity to restrict plant height (Figures 4*a* and 5*a*). At Spring Ridge (2011) and Moree (2012), the Cycocel + Moddus treatment was the most effective at reducing plant height. As a single product, Moddus restricted plant height more than Cycocel at both sites. There was a large difference in the extent of height reduction measured at the two sites, with the maximum height reduction being 7 cm at Spring Ridge in 2011 and 34 cm at Moree in 2012. At the Spring Ridge site, the treatments containing Moddus had no impact on yield compared with the nil treatment, whereas the Cycocel treatment significantly increased the yield of Commander by 8% compared with the nil treatment. The large reduction in plant height at Moree for the Moddus and Cycocel + Moddus treatments resulted in a significant reduction in yield of 8% and 13%, respectively.

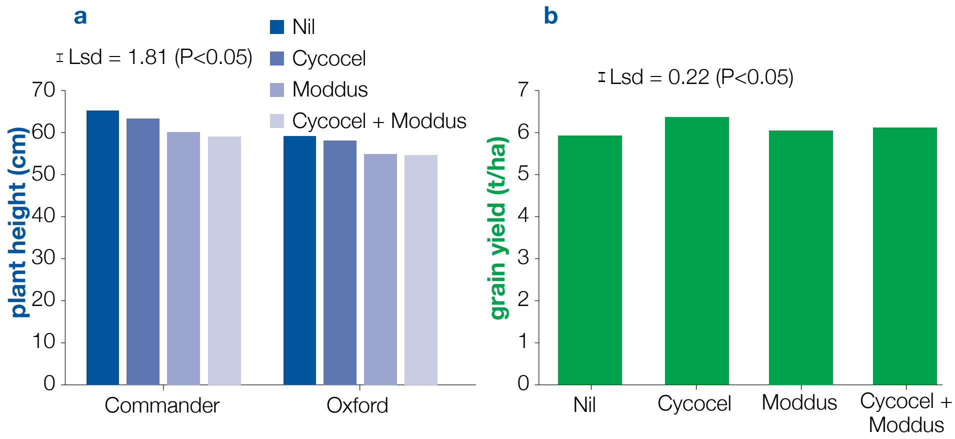

Figure 4: Effect of three PGR treatments on plant height and grain yield of Commander compared with a nil-PGR control at Spring Ridge in 2011.

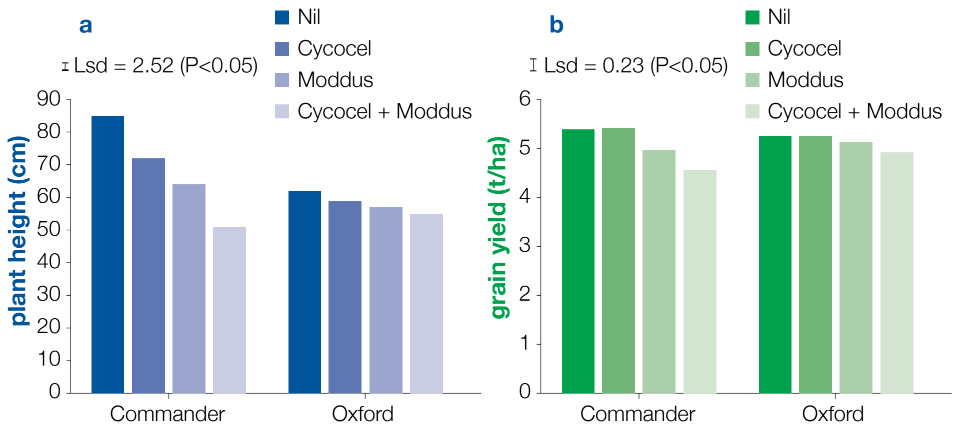

Figure 5: Effect of three PGR treatments on grain yield and plant height of Commander and Oxford compared with a nil-PGR control at Moree in 2012.

In 2008, a trial conducted at the Tamworth Agricultural Institute found a significant yield increase with early (GS25) applications of a PGR combination of Moddus and Cycocel in the absence of lodging. These increases occurred in both durum (EGA Bellaroi) and wheat (EGA Gregory), while no effect was found in Gairdner or Fleet barley. The later application timing resulted in no significant differences compared to the control.

Between 2004 and 2011, field trials were run across Australia by Syngenta, the manufacturer of Moddus, to investigate the value of Moddus applications to Australian cereals to reduce lodging and improve yields. The trials used a range of varieties, climatic conditions and geographical locations and varied application rates were applied at different growth stages. Trials were established as small plots, typically 20–120 m^2, using a randomised complete block design, incorporating three to six replicates.

More information

To find out more about the NSW DPI trials go to: http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/A-snapshot-of-wheat-and-barley-agronomic-trials-in-the-northern-grains-region-of-NSW

Measurements were taken of the effect of Moddus application on plant growth, stem strength, stem-wall thickness, lodging, lodging score and yield as well as grain quality measurements. Several rates of Moddus Evo were assessed for reduction of lodging and enhancement of yield in barley. Moddus Evo applied at rates of 300 or 400 mL/ha was consistently found to improve yields and reduce barley lodging (Figure 6*a*). The optimal growth stage for Moddus application to have the most consistent and greatest impact on yield was GS30–32.

When growth conditions were favourable, a bounce-back effect, where compensation growth occurred, was often observed. To reduce the impact of the bounce-back, a second follow-up application of Moddus Evo was evaluated. When a second application of Moddus was applied at GS37–39, the growth compensation was reduced. When conditions were favourable for bounce-back, the second application resulted in significant yield improvements. The results displayed in Figure 7c is the average across a number of trials where a second application of Moddus Evo was applied; not all of the trials favoured bounce-back growth, which has reduced the overall impact. [15]

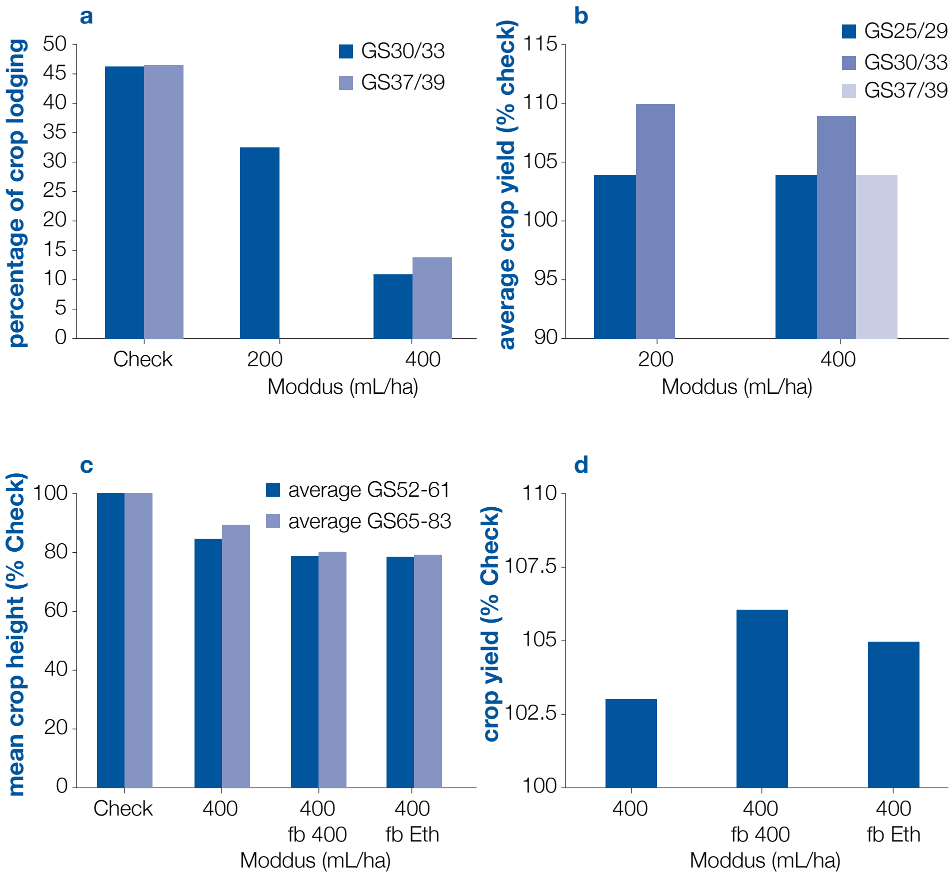

Figure 6: (a) Effect of Moddus concentration on lodging when applied at early and late stem elongation in barley crops. Data are a summary of multiple trials. (b) Effect of concentration and timing of Moddus applications on barley yields, data are percentage improvement from untreated. Applications occurred on healthy growing plants, conditions were not favourable for bounce-back growth. Average data from five trials run in 2007, 80% of the trials did not have lodging. (c) Effect of second application of Moddus on barley stem heights when conditions favour compensatory growth following initial application. (d) Effect of second application of Moddus on barley yields when conditions favour compensatory growth following initial application. Eth, Ethephon applied at 500 mL/ha.

15 B. Staines, LM Forsyth and Ken McKee (2013) Moddus Evo: controlling plant growth for reduced lodging and improved cereal yields, GRDC Update Papers 27 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Moddus-Evo-Controlling-plant-growth-for-reduced-lodging-and-improved-yields

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

Conversely, during the evaluation of effects of Moddus Evo on yield enhancement and reduction in lodging, a few trials had anomalous results, where Moddus Evo application did not improve yield. When these trials were examined, it was found that environmental conditions during the lead-up to Moddus Evo application were poor, with extensive frosting, drought, poor subsoil moisture profile or nutrient deficiencies within the crop. Therefore, it is recommended that Moddus Evo be applied only to healthy growing crops with optimum yield potential.

According to Syngenta, continuing research is aimed at developing a greater understanding of the factors that allow Moddus Evo to improve cereals yields in the absence of lodging. Areas under investigation include:

- Survival and development of secondary tillers in high-biomass crops. Can the use of Moddus Evo open canopies allowing the full development of secondary tillers in high-biomass crops with good soil moisture reserves?
- Enhanced root development. Research suggests that plants treated with Moddus develop larger root systems. Larger root systems may allow plants to access greater soil moisture and nutritional reserves through the latter stages of crop development.
- Redistribution of carbohydrates. The conversion of structural carbohydrates to water-soluble forms to enhance crop yields under dry spring conditions. Preliminary results indicate that Moddus has a significant effect on the concentration of water-soluble carbohydrates in wheat and barley.
- Frost damage reduction. The use of Moddus Evo has been shown to delay mid-season crop development by around 7–10 days. While treated crops 'catch up' and do not incur a harvest time penalty, on average this initial delay results in later flowering and grain-filling in less frost-prone conditions.
- Barley head loss. Dramatic yield improvements were observed with certain barley varieties treated with Moddus Evo due to head retention in conditions favourable to head loss. Further evaluation into the benefits of Moddus Evo in reducing head loss in susceptible barley varieties is under way.

Syngenta concluded from its trials that 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 and it should only be applied to healthy growing crops. [16]

10.3.1 Variety-specific research

Commander⦶ is a malting barley variety that is gaining popularity with growers throughout the northern grains region. However, one of the major limitations to the further adoption of Commander⦶ is its susceptibility to lodging. Apart from being difficult to harvest, lodged crops can limit grain yield by up to 40% and reduce grain quality.

NSW DPI trials investigating lodging management options for Commander⦶ were conducted at Spring Ridge and Tamworth between 2008 and 2011. These options included:

- Varying plant population. This was found to be an effective and easy way to reduce lodging severity. Reducing plant populations from 120 to 80 plants/m² reduced

16 B. Staines, LM Forsyth and Ken McKee (2013) Moddus Evo: controlling plant growth for reduced lodging and improved cereal yields. GRDC Update Papers 27 March 2013, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Moddus-Evo-Controlling-plant-growth-for-reduced-lodging-and-improved-yields

lodging severity by up to 32% in some trials, but further reduction in populations can also significantly reduce yield potential.
- Defoliation. When implemented just prior to stem elongation, defoliation has been shown to reduce lodging severity (by 8–35%) and the area affected by lodging (by 15–45%). However, it must occur prior to stem elongation to avoid yield penalties. Therefore, other methods are preferred.
- Potassium application.
- PGR application. In general, PGRs have resulted in reductions in lodging severity, primarily by reducing plant height by 5–12 cm. In some cases, unexpected yield benefits have occurred with 0.4–0.9 t/ha yield increases observed with PGR application compared with no PGR in the absence of lodging.

Due to the strong susceptibility of Commander to lodging, the combination of appropriate plant populations, defoliation and PGR has been shown to give the greatest reductions in lodging severity.

Overall, trials have shown that some effective management options are available to growers to minimise lodging in Commander. The best lodging management practices are:
- Establish plant populations of ~80–100 plants/m^2. Higher plant population may be targeted in high-yielding situations, but other lodging management practices will also need to be implemented.
- Defoliation through grazing can be used to minimise lodging. The closer to stem elongation that defoliation occurs the more effective lodging risk is reduced.
- Avoid paddocks with excessively high soil N at sowing and, if possible, delay the application of N until stem elongation, when yield can still be increased without driving excessive grain protein concentration.
- PGRs do have the potential to reduce lodging through reduced plant height. A combination of PGR products offers the greatest reduction in lodging severity.
- In situations of high lodging risk, a combination of management practices may be required.

Similar management options for Commander and Oxford barley were investigated in NSW DPI trials at Bellata, Spring Ridge and Tamworth in 2011 (Figure 7).

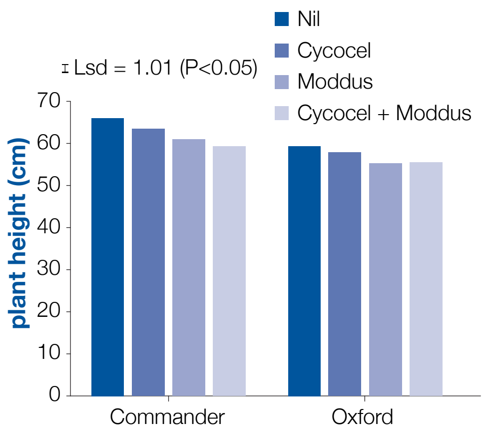

Figure 7: Effect of four PGR treatments on plant height of Commander and Oxford at Spring Ridge 2011.

Restricting the size of the crop canopy or DM production, like restricting plant height, was shown in this trial to be effective in reducing the severity of lodging. Defoliation and plant population were the most effective management strategies for restricting the DM production at anthesis (GS61) and maturity (GS99). On average across sites, defoliation reduced DM yield at anthesis by 5–9%; however, these reductions in DM yield by maturity were negligible. By contrast, the populations of 60 and 80 plants/m^2 maintained significantly lower DM yields than the population of 120 plants/m^2 at both anthesis and maturity (Figure 8).

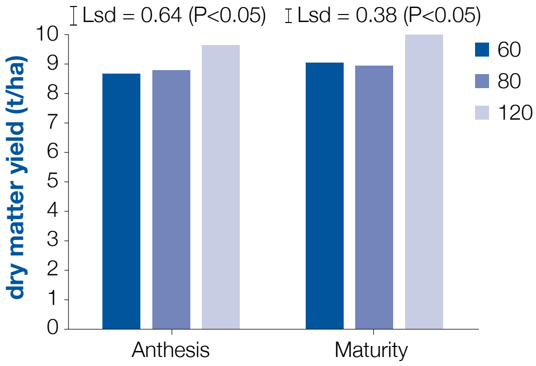

Figure 8: Dry matter yield for the populations of 60, 80 and 120 plants/m^2 at anthesis and maturity.

In summary, this trial found that choosing a variety that is less susceptible to lodging is the most effective management option for reducing the losses from and severity of lodging. Where a variety susceptible to lodging such as Commander is grown, defoliation prior to stem elongation can reduce the severity of lodging and limit the canopy size at anthesis. It is essential that defoliation does not occur beyond stem elongation (GS31) as significant yield penalties could be expected. Maintaining plant populations at ~80 plants/m^2 enabled DM yield to be restricted throughout the growing season, without significantly limiting yield. Of the PGR treatments, the combination of Cycocel and Moddus reduced the severity of lodging to the greatest degree. To read more about the results, go to: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/430291/Northern-grains-region-trial-results-autumn-2012.pdf

A further trial on lodging management of Commander was conducted in 2012 by NSW DPI at sites in Breeza, Gurley and Moree (Table 2). In all trials, PGR treatments were shown to reduce lodging to some degree, which was most likely a function of the reduced plant height obtained from PGR applications. Yield responses to PGR application ranged from –13% to +16% for Commander and Oxford compared with the untreated control. Commander was usually more responsive to the application of PGRs than Oxford. Of the PGR treatments, the combined Cycocel and Moddus treatment resulted in the most consistent reduction in plant height and greatest responses in grain yield, whether negative or positive.

These results highlight the variability in responses to PGR application, which makes it difficult to predict the economic benefit of using PGRs within cropping systems.

Table 2: Lodging scores (scale 0–9, where 0 is standing and 9 is flat on the ground) at harvest for the Moree and Breeza sites. Minus and plus relate to defoliation treatments

PGR Treatment	Moree				Breeza			
	Commander		Oxford		Commander		Oxford	
	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus
Nil	3.4	1.9	0.0	0.0	8.5	6.5	3.5	3.3
Cycocel®	2.2	1.5	0.0	0.0	7.5	5.3	3.0	3.0
Moddus®	0.0	1.0	0.0	0.0	–	–	–	–
Cycocel® + Moddus®	0.0	0.0	0.0	0.0	4.8	4.3	2.0	1.5

The much greater severity of lodging at Breeza compared with Moree was ostensibly due to irrigated conditions at Breeza. A dry finish to the season ensured lodging of Commander remained minimal at Moree. To read more about this trial, go to: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf