Effects of plant growth regulators that reduce stem height on yield of wheat in southern Australia

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Abstract

The experiments reported here were designed to investigate the potential of the plant growth regulators (PGRs) Moddus and Cycocel, to increase yields in dryland wheat production systems of the southern Australian wheat belt. Experiments were conducted on wheat crops at Wagga in southern NSW (cultivar: EGA Gregory) and Swan Hill in Victoria (cultivar: Yitpi) in 2010. Crops were sprayed with varying rates and combinations of Moddus and/or Cycocel applied at three different crop growth stages, Z14, Z25 and Z31/32. Measurements included crop height, canopy greenness, lodging, stem non-structural carbohydrates (NSC), dry matter production, yield and yield components.

The application of the PGRs was found to significantly decrease the height of treated plants, especially when applied from the beginning of stem elongation Z25 through to Z31/32. There were inconsistent effects of applying PGRs on yield. Combining the analysis of yields of the two sites revealed that yields increased by up to 0.4 t/ha when high rates (600 ml/ha) of Moddus were applied. Significant increases in yield at both sites were associated with increased ear bearing tillers and increased grain density. The results are discussed with respect to the prevailing seasonal conditions and the need for further broad-scale field testing.

Key Words

trinexapac-ethyl, chlormequat

Introduction

The effects of the plant-growth regulators (PGRs) Moddus and Cycocel in dryland wheat production systems have yet to be widely explored in Australia. Recent studies have shown that these PGRs, especially Moddus, may significantly affect yield, other than through a reduction in lodging (Espindula *et al.* 2009; Rajala and Peltonen-Sainio 2001). In dryland wheat production systems, where water is often a major yield-limiting factor, PGRs that can reduce the growth of the canopy could influence the pattern of water use and hence grain yield (Passioura and Angus 2012). Applications of Moddus and Cycocel are associated with reductions in biomass accumulation during the growing season, resulting in less biomass at anthesis (Cox and Otis 1989; Rajala and Peltonen-Sainio 2001). Grain filling of wheat in southern Australia is often completed in conditions of limited soil moisture as temperatures rise and evapotranspiration requirements are not satisfied by rainfall alone (Fischer 1979;

Passioura and Angus 2012). Reductions in biomass production prior to anthesis can result in higher levels of soil moisture available at anthesis which can subsequently be used to support grain growth. Each extra mm of soil moisture used after anthesis can contribute up to 60 kg to grain yield (Passioura and Angus 2012).

The reduction in plant biomass by PGRs may also have negative consequences for grain yield through reduced photosynthetic area and lower levels of stored reserves for re-translocation at grain filling time (Espindula *et al.* 2009). Lower yield could also be caused by direct effects on yield components such as kernel number per ear or ears/m^2 depending on timing of applications. Hence, it is uncertain whether the use of such PGRs will have a positive or negative impact on grain yields in dry land farming systems of southern Australia.

Materials and Methods

Two field experiments were conducted in 2010 to analyse the effects on grain yield of applying two growth regulators, trinexapac ethyl, commercially known as Moddus, and chlormequat, commercially known as Cycocel, at three different timings and at varying application rates . The two experimental sites, one near Wagga Wagga in southern New South and the other near Swan Hill in the North West of Victoria were established in commercially sown paddocks of the wheat cultivars EGA Gregory (sown May 11 at 76 kg/ha) and Yitpi (sown May 13 at 60 kg/ha). For both sites the design of the experiment was a randomised complete block, with four replicate blocks randomised in two directions. The treatments consisted of PGR treatments, Moddus at 12.5, 25, 50, 100 and150 g active ingredient (ai)/ha, chlormequat at 582 g ai/ha and Moddus + Cycocel at 100 + 582 g ai/ha. Each treatment was applied at three crop growth stages (see Zadoks *et al.* 1974) "early" (Z14.5), "mid" (Z25) and "late" (Z31/32). Actual dates of application are presented in Table 1.

Table 1 Dates and average crop growth stage (Zadoks *et al.* 1974) at times of PGR application.

Application Time	Growth Stage	Wagga	Swan Hill
Early	Z14.5	28/06/10	29/06/10
Mid	Z25	20/07/10	21/07/10
Late	Z31/32	13/08/10	17/08/10

Plant height was measured on 10 randomly selected tillers per plot between growth stages Z31 and Z75 (Zadoks *et al.* 1974). Plant height (cm) was recorded for 10 randomly selected plants per plot similar to the method of Espindula *et al.* (2009) and Rajala and Peltonen-Sainio (2002). Measurements of height were made from the ground to the tip of the ear apex, excluding the awns, following the procedure of Espindula *et al.* (2009). Lodging was scored at grain harvest at both sites using the method of Fischer and Strapper (1987), and calculated using the following formula: Lodging score = % of plot area lodged × angle of lodging/90. The angle was included to represent the degree to which the crop canopy was compressed by lodging (Fischer and Stapper 1987). The lodging score ranged from 0 (not affected) to 100 (whole plot completely lodged). Lodging was scored at the Wagga site twice prior to harvest on the Nov. 1 and 15 after large rainfall events which caused the crop to noticeably lodge.

Anthesis dry matter was measured by randomly harvesting four 0.5 m row cuts and drying at 70º C for 48 hours then weighing (the same procedure for all other measurements involving dry matter). Grain harvest at both sites took place on the 7th of January using plot headers (giving a sampled area of 1.8 x 12 m per plot). Total grain harvested for each plot was collected, weighed and sub sampled in order to asses grain quality (protein and screenings) and moisture content. Yield (t/ha) was adjusted to 12% moisture content. For yield component analysis, cuts were made for each plot on the 7th and 10th of December at Wagga Wagga and Swan Hill respectively, both cuts were made before significant weather damage occurred. Four random 0.5 m cuts along the drill rows were made in each plot avoiding any apparently diseased areas. From these, plot dry matter, density of ears and harvest index were all measured and calculated.

All statistical analyses were carried out using GenStat V 13.0 (VSN International, UK). Analysis of variance was carried out on most variables with the treatment structure "Control/ (Treatment*Time)" that enabled interactions between treatment and time to be analysed and compared back to the control. Accounting for any effects of disease on total plot yield at both sites was achieved by including a covariate (Normalized difference vegetative index, NDVI measured using a GreenSeeker™ Handheld Optical Sensor at anthesis) in the analysis. Grain yield was the only variable which was analysed across sites using ANOVA. This was used to test for effects of experiment/location and interactions with treatments. Correlation matrices were used to examine the existence of relationships between yield components and other measured variables.

Results

Total annual rainfall was above decile 9 for both sites. At Wagga Wagga, growing season rainfall from sowing (May 11) to harvest (Dec. 17) was 650 mm, with the 144 mm occurring after 1 Dec. considered too late to significantly increase yield. At Swan Hill growing season rainfall from sowing (May 13) to harvest (Dec. 9) was 449 mm with the site receiving 172 mm of rainfall between sowing and anthesis (10th of October), and a further 277 mm from anthesis to maturity. There was 125 mm of rainfall after Nov 24 which was unlikely to contribute significantly to the yield of the crop.

There were significant treatment by time of application interactions for crop height at anthesis for both sites (Table 2). Cycocel had no significant effect on crop height at each site, and the Moddus+Cycocel treatment did not differ from the Moddus only treatment at the same concentration. Hence, the Cycocel treatments were omitted from Table 2. Later times of application (particularly at early stem elongation) and higher concentrations of Moddus (greater than 25 g ai/ha) were most effective at reducing stem height at both sites (Table 2). None of the plant growth regular treatments affected lodging at Swan Hill. In contrast at the Wagga site, lodging was reduced by the treatments that had the most marked effects on crop height. Indeed there was a significant negative correlation between crop height and lodging score ($r = -0.71$, $P<0.01$).

Table 2 Crop height (cm) in response to application of Moddus at a range of rates Wagga and Swan Hill. Treatments were applied at three different stages.

Treatment	Wagga			Swan Hill		
	Z14.5	Z25	Z31	Z14.5	Z25	z31
Control	**111.1**			**99.4**		
Moddus (g ai/ha)						
12.5	111.5	108.1	107.5	99.6	101.7	100.1
25	110.4	109.1	108.9	99.0	99.0	97.9
50	110.8	107.4	102.2	99.0	100.1	96.8

100	108.5	99.1	90.1	100.4	95.5	87.1
150	104.3	89.4	81.5	97.4	95.9	83.5
lsd* (P<0.05)		3.2			3.7	

* Least significant difference (lsd) values are for comparisons between treatments and control only

There were no significant treatment effects on anthesis dry matter at the Wagga site. At Swan Hill there were significant differences between treatments in dry matter at anthesis but these were small and no treatment was significantly different from the control. Yield was significantly increased by applications of Moddus at concentrations at or above 50 g ai/ha and applied at the Z25 or Z 31 stages at the Wagga site. Cycocel and the Moddus+Cycocel treatments also increased yield significantly at that site (Table 3). The average yield increase (of significant treatments) compared to the control was 0.47 t/ha. In contrast, only one PGR treatment increased yield relative to the control at Swan Hill and that was Moddus at the highest concentration (150 g ai/ha) applied (increasing yield by 0.52 t/ha). There was no effect of timing of application or interaction between timing and PGR treatment at this site (Table 3). There were significant main effects of PGR treatment (but not timing of application or an interaction between the two) when cross site analysis was performed. Yield increases of 0.3 to 0.37 t/ha compared to the control occurred in the Moddus treatments at the two higher application rates and the two Cycocel treatments. There were no effects of any of the treatment combinations on grain protein or screenings at either site.

Yield component analysis showed that grain yield was closely related to kernel number/m^2 (KNO). There was no relationship between grain weight and yield at Swan Hill and a weak negative relationship between the two at Wagga. Surprisingly, given the timing of the late application it was ear number/m^2 that was most closely related to grain yield and KNO at both sites. This may have arisen out of the reduced competition between ear bearing tillers in those treatments where height was significantly affected by the PGR treatments. However it does not explain the response to the Cycocel-only treatment at Wagga or in the combined analysis as this treatment did not affect stature.

Table 3. Grain yield (t/ha) in response to plant growth regulator applications at different times of application (significant at Wagga but not Swan Hill). A "combined" analysis used data from the two sites. Moddus treatments are signified by an M followed by the application rate in g ai/ha. The two treatments that involved the application of Cycocel are explained in the text.

	Wagga				Swan Hill	Combined
Treatment		Z14.5	Z25	Z31		
Control	3.85				4.82	4.35
M 12.5		3.79	3.79	4.06	5.24	4.60
M 25		4.04	3.92	3.82	4.6	4.31
M 50		4.03	4.40*	4.23*	4.68	4.42
M 100		4.03	4.23*	4.55*	5.06	4.65*
M 150		4.08	4.38*	4.31*	5.34*	4.72*
Cycocel		3.95	4.22*	4.26*	5.24	4.73*
M+Cycocel		4.19*	4.40*	4.23*	5.19	4.72*

* denotes treatment that were significantly (P<0.05) different than the control.

Conclusion

This study shows there is modest potential for the application of Moddus applied with or without Cycocel to increase yields of wheat. However, the PGRs did not affect anthesis dry matter as had been reported in other studies (Cox and Otis 1989; Rajala and Peltonen-Sainio 2001) so it is most likely that yield differences occurred due to changes in yield components not related to post-anthesis water use (see Passioura and Angus 2012). Ear density was the yield component most affected by PGRs at both sites whether lodging occurred (Wagga) or not (Swan Hill). Due to the variability within and between sites, further research is required before recommendations could be made. Moreover, these experiments were conducted in an extreme high rainfall year and would need to be further replicated in dryland farming systems across the southern Australian wheat belt to clarify which combinations will profitably and consistently increase yields.

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