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In-season agronomic manipulation of early sown spring wheat; to delay flowering and reduce frost effects – Wagga Wagga 2023

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Key findings

- This study showed it is possible to reset the flowering time for early sown quick–mid spring wheat varieties through in-crop mechanical defoliation, apical pruning, during early stem elongation (GS31–32).
- Depending on the intensity of the defoliation treatment, anthesis, was delayed by up to 25 days for Scepter⫯ from a 5 April sowing date (SD), which resulted in a significant increase in yield compared with the undefoliated control at 5.49 t/ha vs 4.31 t/ha.
- The heavy defoliation treatment enabled Scepter⫯ to reach anthesis on 25 September from the 5 April sowing, around the start of the optimum flowering period (OFP) for this environment, as opposed to the untreated control, which flowered on 31 August.
- Although apical pruning was shown to increase the yield potential of early sown quick–mid spring wheats, it was still not able to out-yield Illabo⫯, a locally well adapted mid winter wheat variety sown in its preferred sowing window, which achieved the highest yield of 7.40 t/ha.
- The best performing heavily defoliated Scepter⫯ was only able to achieve 89% (5.49 t/ha) of the yield from Scepter⫯ sown in its preferred sowing window (6.19 t/ha).
- Yield potential tends to be optimised when the correct phenology type is sown in its preferred window, so that it flowers within the OFP for a given environment.
- Apical pruning should only be considered as a possible management strategy when quick–mid spring wheats have been sown well outside their preferred window and/or are developing such that there is an increased risk of yield loss due to frost risk.

Keywords Apical pruning, mechanical defoliation, anthesis, grain yield, grain protein, optimal flowering period

Introduction

The aim of this experiment was to investigate the effect of mechanical defoliation and intensity, as a method of 'resetting flowering time' to stabilise the yield potential of early sown and/or quick maturing spring wheats. If successful, this would provide a strategy to reset flowering time and slow down the development of spring varieties sown either too early and/or developing too quickly.

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Apical pruning by mechanical defoliation during early stem elongation (GS31–32) aims to remove and/or impede the emerging apical meristem/shoot apex, to impose a phenology reset on fast developing spring wheat crops (Porker et al. 2022). This is in contrast to what is generally the accepted practice when grazing dual-purpose winter wheats where defoliation/grazing is not recommended after the onset of stem elongation (i.e. GS30) so as to avoid damage to the emerging apical meristem.

The objective of this approach was to delay crop development so that flowering occurs within or close to the OFP for a given environment. This aims to:

- balance the risks of frost damage during flowering and moisture and heat stress during grain fill
- minimise production risk
- optimise grain yield potential.

Site details

Location	Wagga Wagga Agricultural Institute
Soil type	Red chromosol
Paddock history	Canola (2022), lupin (2021)
Sowing	Direct drilled with DBS tynes spaced at 250 mm using a GPS auto-steer system
Target plant density	120 plants/m^2
Soil pH_{Ca}	6.1 (0–5 cm); 5.4 (5–10 cm); 5.1 (10–15 cm); 5.2 (15–20 cm)
Mineral nitrogen (N)	142 kg N/ha at sowing (1.2 m depth)
Fertiliser	• 100 kg/ha mono-ammonium phosphate (MAP), treated with 200 mL/ha flutriafol at sowing. • In addition, a total of 110kg N/ha as urea (240 kg/ha urea) was applied after sowing. Of the 110kg N/ha, 46 kg N/ha (100 kg/ha of urea) was applied on 19 June with the remaining 64 kg N/ha (140 kg/ha of urea) applied to all treatments on 26 July.
Weed control	• Knockdown: 1.0 L/ha Crucial® (600 g/L glyphosate) at sowing. • Pre-emergent: 118 g/ha Sakura® + 1.6 L/ha Avadex® Xtra + 1 L/ha TriflurX® incorporated by sowing (pre-sowing – SD1: 5 April; SD2: 5 May; SD3: 15 May). • In-crop: 600 mL/ha MCPA 570 LVE + 25 g/ha Paradigm® Arylex® + 5% Uptake spray oil (27 June).
Disease and pest management	• Seed treatment: 2 L/t Hombre® Ultra + 2.6 L/t EverGol® Energy. • In-crop: 250 mL/ha Soprano® 500 + 0.25% SpreadWet 1000 (SD1 only on 1 June). All other sowing dates including SD1 received 400 mL/ha AmistarXtra® (27 June), 200 mL/ha Bumper® 625 (24 July) 400 mL/ha AmistarXtra®+600 mL/ha chlorpyrifos (17 August), 300 mL/ha Prosaro® 420SC (6 September).
Harvest date	27 November 2023

Rainfall	• In-crop
	  • 227 mm (April–October, Table 1)
	  • Long-term average: 352 mm	

Severe temperature events	• Three heat stress events (days >30 °C): 32.8 °C (18 September), 31.9 °C (19 September) and 35.3 °C (21 October). • Eleven frosts (minimum temperature [T min] <0 °C ≥−2.0 °C) including: −2.0 °C (15 August), −1.0 °C (24 August) and 5 events (T min ≤−1.0°C) recorded in the first 2 weeks of September including −1.4 °C on 6 September (Figure 1). There was also 0 °C recorded on 17 October.	

Table 1 In-crop monthly rainfall.

Month	April	May	June	July	August	September	October
Rainfall (mm)	72	13	58	27	32	5	20

Growing conditions

The site had approximately 80 mm of plant available water (PAW) at sowing, after 320 mm of fallow rain (November 2022 – March 2023). This combined with April rain of 72 mm and follow-up rain of 58 mm in June (Table 1), meant that all sowing dates were successfully established under good soil moisture conditions. In contrast, the spring was characterised by a warm, dry September, with temperatures exceeding 30 °C on 2 consecutive days, 18 and 19 September with only 5.2 mm of rain recorded for the month (Figure 1). Consequently, there was the potential for yield penalty associated with later flowering, particular for the longer season varieties.

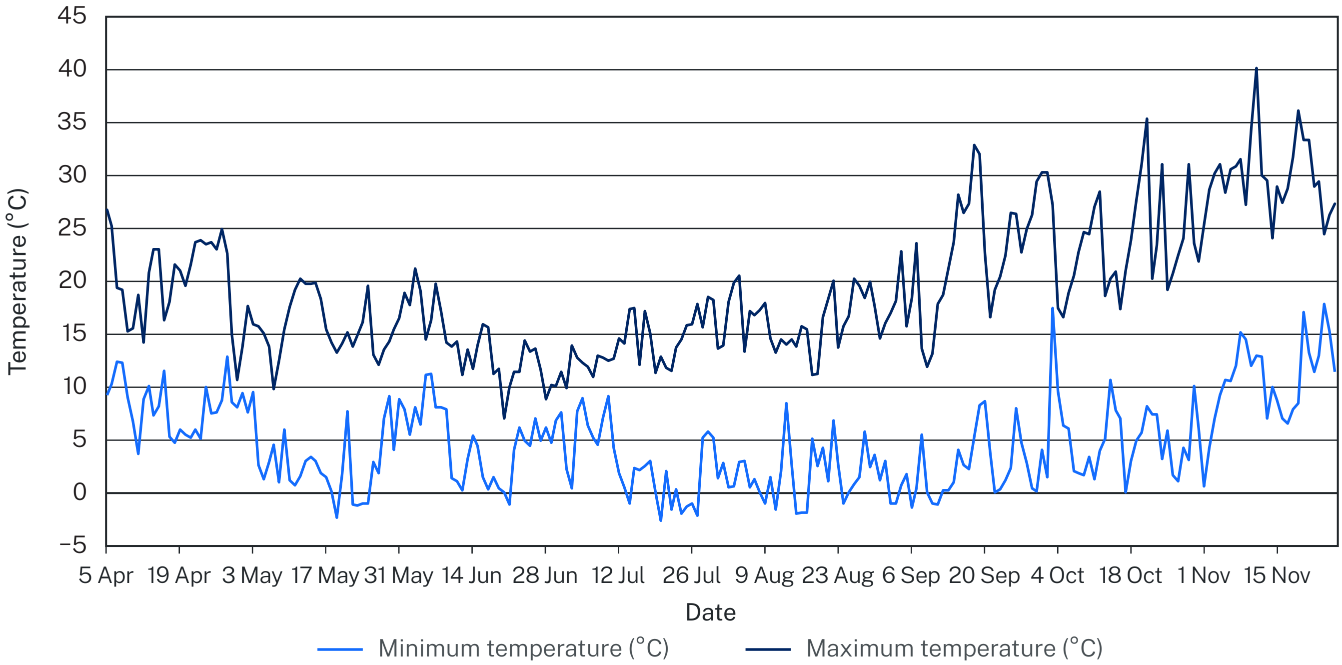

Figure 1 Minimum temperature (T Min) and maximum temperature (T Max) recorded at the Wagga Wagga site in 2023.

Frosts also affected the 2023 growing season, particularly in late August and early spring, with 5 frosts (T min ≤−1.0 °C) recorded in the first 2 weeks of September. These coincided with the critical development stage of early flowering, resulting in the potential for significant yield penalties.

Treatments

Variety

Six wheat genotypes (Table 2), varying in phenology type, were sown on 3 sowing dates.

Sowing date (SD)

- SD1: 5 April
- SD2: 5 May
- SD3: 15 May

Table 2 Phenology responses of genotypes according to the Australian Cereal Phenology Classification (Celestina et al. 2023).

Phenology types	Varieties
Slow winter (SW)	DS Bennett⊕
Mid winter (MW)	Illabo⊕
Slow–very slow spring	LRPB Nighthawk⊕
Mid spring (MS)	Rockstar⊕
Quick–mid spring (Q–MS)	Scepter⊕
Quick spring (QS)	Vixen⊕

Mechanical defoliation

Mechanical defoliation treatments were applied at differing intensities based on cutting height using a slasher. Vixen⊕ for both SD1 and SD2 and Scepter⊕ for SD1, had treatments applied when growth stages were ≥GS31 and ≤GS32 (Table 3). The defoliation intensity levels (Figure 2) were:

- heavy cut 2–4 cm from the plant base
- medium cut 4–8 cm from the plant base.

Table 3 Date defoliation treatments were applied and key growth stage timings.

Sowing date and variety	Defoliation date	GS31	GS32
SD1 Vixen	25 May	25 May	5 June
SD1 Scepter	15 June	5 June	19 June
SD2 Vixen	13 July	12 July	24 July

Crop measurements included flowering time, biomass at anthesis (GS65), harvest index, grain yield and yield components.

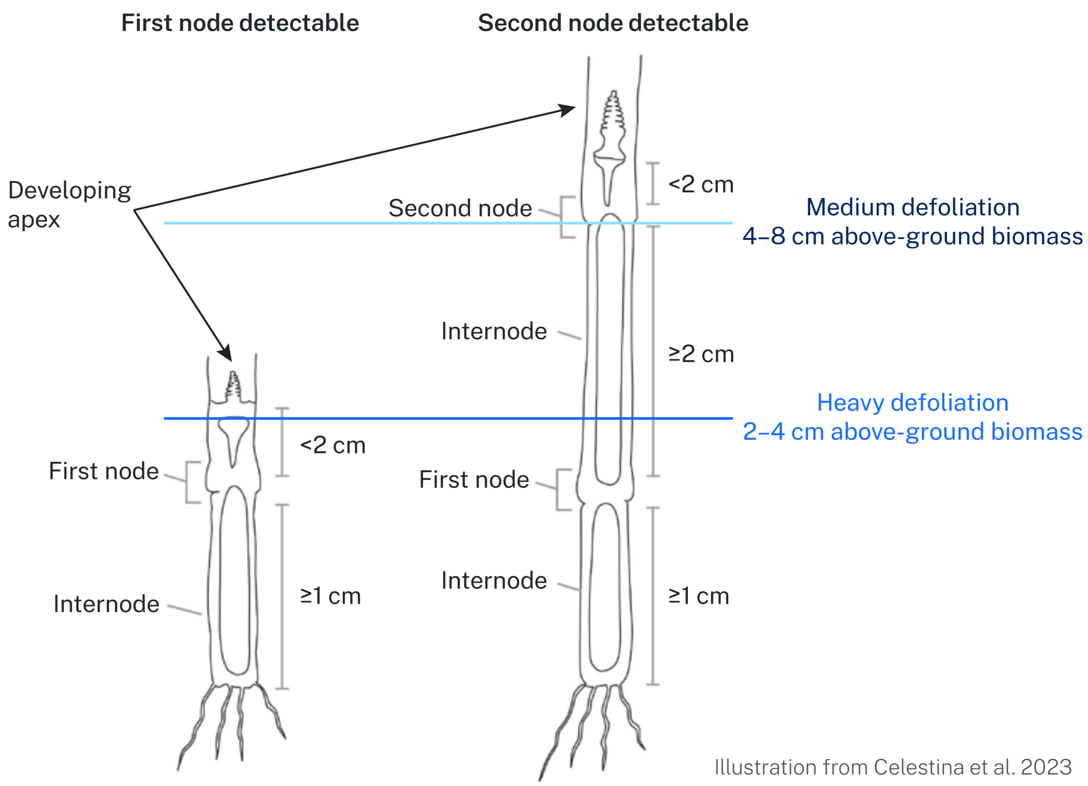

Figure 2 Schematic of defoliation intensities at GS31–32.

Results

This experiment demonstrated that apical pruning delayed or reset the flowering time of spring wheat varieties sown earlier than their ideal window. For Scepter⫯, sown on 5 April (SD1) approximately 4 weeks earlier than the start of its recommended sowing window for this environment (Matthews et al. 2023), the medium and heavy defoliations delayed anthesis (GS65) by 21 and 25 days respectively (Table 4). Likewise, the medium and heavy defoliation treatments, when applied to Vixen⫯ a quicker spring type than Scepter⫯ sown approximately 5 weeks earlier than its preferred window (SD1), were able to delay GS65 by 13 and 9 days respectively. The difference between the 2 varieties in terms of delay in anthesis, in response to defoliation treatments for SD1, might have been due to differences in the actual growth stage when the treatments were applied. Vixen⫯ in SD1 for example, had the defoliation treatments applied just as it reached GS31, whereas Scepter⫯ was closer to GS32 (Table 3). Vixen⫯ for SD2 was also closer to GS31 than GS32, resulting in only a 6 day delay in anthesis. These results are consistent with previous findings where anthesis delays in response to defoliation was shown to be influenced by intensity and the growth stage at which the defoliation treatment was applied (Graham et al. 2023). The more advanced the growth stage and defoliation intensity, the greater the delay in time to reach anthesis.

Table 4 Effect of defoliation treatment on flowering time and grain yield (t/ha).

Sowing date and variety	Treatment	Flowering date	Defoliation effect (days delayed)*	Grain yield (t/ha)
SD1: 5 April				
Vixen	Untreated control	25 August †	–	0.93
Vixen	Medium defoliation	3 September	9	2.07
Vixen	Heavy defoliation	7 September	13	2.44
Scepter	Untreated control	31 August	–	4.31
Scepter	Medium defoliation	21 September	21	4.74
Scepter	Heavy defoliation	25 September	25	5.49
Rockstar	Phenology control	6 September	–	6.53
LRPB Nighthawk	Phenology control	20 September	–	6.67
Illabo	Phenology control	22 September	–	7.40
DS Bennett	Phenology control	5 October	–	6.24
SD2: 5 May				
Vixen	Untreated control	19 September	–	6.61
Vixen	Medium defoliation	23 September	4	5.79
Vixen	Heavy defoliation	24 September	6	5.24
Scepter	Phenology control	22 September	–	6.19
Rockstar	Phenology control	25 September	–	6.01
LRPB Nighthawk	Phenology control	3 October	–	5.07
Illabo	Phenology control	2 October	–	4.97
DS Bennett	Phenology control	10 October	–	4.93
SD3: 15 May				
Vixen	Phenology control	25 September	–	5.77
Scepter	Phenology control	28 September	–	5.44
Rockstar	Phenology control	28 September	–	5.43
LRPB Nighthawk	Phenology control	7 October	–	4.34
Illabo	Phenology control	5 October	–	4.48
DS Bennett	Phenology control	10 October	–	4.25
P value				$P<0.0001$
l.s.d. ($P<0.05$)				0.52

* Defoliation effect on anthesis (days delayed) relative to untreated control.

† 50% anthesis date.

Grain yield

Grain yield results for this study showed that Illabo⦶, a mid winter phenology control sown in the early part of its preferred sowing window on 5 April (SD1), and flowering on 22 September around the start of the OFP for this environment, achieved the highest yield of 7.40 t/ha (Table 4). Illabo⦶ from SD1, was also the only variety × sowing date combination that was significantly higher yielding than the traditional on-time sown SD2 quick–mid spring Scepter⦶. When sowing was delayed, grain yield for Illabo⦶ declined in response to later flowering, due principally to a corresponding increase in heat and moisture stress, and exhibited a typical yield response curve for this phenology type in this environment: yield declining with delays in sowing date. The other slower phenology types, DS Bennett⦶ and LRPB Nighthawk⦶, displayed similar yield responses, with yield declining in response to delays in sowing date and hence anthesis.

In contrast, when Scepter⦶ was sown on 5 April (SD1) much earlier than it's preferred window, it suffered a 30% or 1.88 t/ha yield penalty (SD1: 4.31 t/ha vs SD2: 6.19 t/ha). This was due to frosts during the critical growing period, Scepter⦶ having reached anthesis on 31 August (Table 4). When Scepter⦶ was sown in a more favourable sowing window, on

5 May (SD2), it achieved its highest yield of 6.19 t/ha, reaching anthesis on 22 September. Importantly, when the heavy defoliation treatment was applied to Scepterᶲ for SD1, it was able to delay anthesis by 25 days, resulting in a 1.18 t/ha or 27% increase over the untreated control (5.49 t/ha vs 4.31 t/ha). The medium defoliation treatment, although able to delay anthesis for Scepterᶲ for SD1, resulting in a slight, but not significant, increase in yield. Although findings showed that targeted defoliation treatments for Scepterᶲ for SD1, were able to delay anthesis, to a similar period as the Scepterᶲ phenology control for SD2, there was still a yield penalty with the best performing heavy defoliated treatment Scepterᶲ SD1, achieving 89% of the Scepterᶲ yield for SD2.

Results for Vixenᶲ, a quick spring type sown much earlier (i.e. SD1) than its preferred window, showed that there was a severe yield penalty associated with early flowering. This was related to a number of frosts during the critical developmental period in 2023, which included a −1.0 °C on 24 August and 5 further events (T min ≤−1.0° C) recorded in the first 2 weeks of September. Although these defoliation treatments were able delay flowering and resulted in significant increases in yield over the untreated control, they were still well below yields achieved for later sowing dates (SD2 and SD3). The best performing, the heavy defoliation Vixenᶲ treatment for SD1 only achieved 37% and 42% respectively of the Vixenᶲ controls for SD2 and SD3. Importantly, it should be noted that when sowing date was delayed and defoliation treatments were applied to Vixenᶲ in SD2, there was yield penalty associated with defoliation and intensity that was related to a decrease in biomass accumulation (Table 5).

These results further highlight the need to sow the correct phenology type in its preferred sowing window. Findings from this experiment did, however, show that defoliating quick wheats early did delay anthesis and was capable of alleviating some of the yield penalties associated with early flowering and frost risk. An understanding of frost risk and heat and moisture stress as it relates to phenology type and sowing options for a given environment is essential to optimise yield potential and manage season risk factors.

Grain quality

Results for Scepterᶲ in this study, showed that there was both a decrease in thousand seed weight (TSW) and grain protein (%) in response to the defoliation treatments for SD1 (Table 5). Although, in terms of grain yield, there was no significant difference between the untreated Scepterᶲ control and the medium defoliation, there were significant differences in both TSW and grain protein. The decrease in grain protein and TSW was further exacerbated under the heavy defoliation treatment, although it should be noted that grain yield was significantly greater than both the control and medium defoliation treatments. These results underline the need to consider adequate nitrogen to compensate for loss of biomass due to defoliation, in order to achieve both yield potential and to meet targeted grain protein classifications.

Table 5 Effect of defoliation treatments on grain yield, GS65 biomass, grain protein and seed weight.

Sowing date and variety	Treatment/timing	Grain yield (t/ha)	GS65 DM (kg/ha)	Grain protein (%)	Seed weight (g/1000)*
SD1: 5 April					
Scepter	Untreated control	4.31	15482	15.21	49.35
Scepter	Medium defoliation	4.74	10899	12.71	43.69
Scepter	Heavy defoliation	5.49	8829	10.71	40.03
Vixen	Untreated control	0.93	14297	15.34	45.70
Vixen	Medium defoliation	2.07	12550	15.76	48.15
Vixen	Heavy defoliation	2.44	11421	15.46	46.84
SD2: 5 May					
Scepter	Untreated control	6.19	14258	13.63	34.88
Vixen	Untreated control	6.61	14570	12.83	30.63
Vixen	Medium defoliation	5.79	10591	12.01	30.66
Vixen	Heavy defoliation	5.24	8182	12.96	32.94
SD3: 15 May					
Scepter	Untreated control	5.44	12600	12.42	32.56
Vixen	Untreated control	5.76	11801	13.61	28.64
P value		*P*<0.0001	*P*<0.0001	*P*<0.0001	*P*<0.0001
l.s.d. (*P*<0.05)		0.52	1348	2.36	2.43

* Thousand seed weight (TSW).

Summary

This study demonstrated that it is possible to reset the flowering time of early established spring wheat varieties through in-crop mechanical defoliation during early stem elongation (GS31–32). Depending on the intensity of the defoliation treatment, anthesis for example, was delayed by up to 25 days for Scepter$^{\phi}$ from SD1 and resulted in a significant increase in yield compared with the control. The heavy defoliation treatment enabled Scepter$^{\phi}$ to reach anthesis on 25 September for SD1, around the start of the OFP for this environment, as opposed to the untreated control that flowered on 31 August. Importantly, yield responses and corresponding delays in anthesis were observed to be greatest under heavy defoliation from an early establishment/sowing date: both Scepter$^{\phi}$ and Vixen$^{\phi}$ showing significant yield improvements compared with doing nothing. The grain quality results for the defoliated Scepter$^{\phi}$ also highlighted the need to consider adequate nitrogen to compensate for biomass loss from defoliation in order to achieve both yield potential and to meet targeted grain protein classifications.

It was also observed that with delays in establishment/sowing, for Vixen$^{\phi}$ for SD2 for example, increases in defoliation intensity resulted in decreased yield, even though anthesis was delayed. The decrease in yield potential was mostly likely associated with a decline in biomass accumulation due to defoliation and the decreased probability of frost events.

Although apical pruning was shown to increase the yield potential of early sown quick–mid spring wheats, it was still not able to out-yield Illabo$^{\phi}$, a locally well adapted mid winter wheat variety sown in its preferred sowing window. Furthermore, compared with Scepter$^{\phi}$ sown in its preferred sowing window (SD2), the best performing heavily defoliated Scepter$^{\phi}$ from SD1 was only able to achieve 89% of the Scepter$^{\phi}$ yield for SD2.

In conclusion, it is possible to reset/delay anthesis in early sown spring wheats using apical pruning as a management strategy to offset the risk of yield loss from the increased probability of frosts. The results from this study do, however, underline that yield potential tends to be optimised when the correct phenology type is planted in its preferred sowing window so that it flowers within the OFP for a given environment. On this basis, apical pruning should only be considered as a possible management strategy when quick–mid spring wheats have been planted well outside their preferred sowing window and/or development means that there is an increased risk of yield loss due to frost.

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