Apical pruning to delay flowering time and increase yield in early sown spring wheat

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Abstract

The timing of autumn rainfall which allows germination is variable, and spring wheat cultivars popular in South Eastern Australia have a narrow period during which they must germinate in order to flower during the optimal period. Growers need access to a range of genetic and management tools to more reliably ensure optimal flowering times are achieved and widen available sowing windows. We evaluated pruning of the emerging apical meristem in early sown and fast-maturing spring wheats using chemical and mechanical defoliation. Interventions sought to slow development in precocious crops (emerged too early/developing too quickly) that germinate before their optimal time. Apical pruning by defoliation and removal of main stem apices during early stem elongation was reliably able to reset development of precocious spring wheat and increase yield relative to untreated controls. Mechanical defoliation was the most promising treatment and delayed flowering from 9 to 18 days and increased yield by 0 to 1.6 t/ha compared to the untreated early sown and fast-maturing spring wheat control. Yields of pruned spring wheat were comparable to early sown winter wheat, meaning growers may only require one cultivar and can still spread sowing dates substantially while reducing risk of emergence outside of optimum.

Keywords

Crop development, vernalisation, flowering time, adaptation, apical dominance, defoliation

Introduction

Agronomic research conducted in Australia has aimed to coincide critical periods of yield determination in wheat (*Triticum aestivium*) with climatically optimal conditions for growth (Hunt et al., 2019a) and has focused on using sowing date matched with cultivar development in order to flower at the optimum time. This contrasts with perennial crop management where they do not have the ability to use sowing date to manage crop development. Sowing winter wheat earlier is one method to capitalise on early rain, and increase water limited potential yield compared to later sown spring wheat (Hunt, 2017; Hochman and Horan, 2018; Flohr et al., 2019; Hunt et al., 2019b). Winter wheats must be established early as they are prone to a yield decline from delayed emergence. A major barrier to adoption of winter wheats is the requirement for growers to keep seed of multiple cultivars without certainty that they can use them in any given year. This is due to variable timing of autumn rainfall, and absence of accurate forecasts to ensure early establishment (prior to the 20th April) if sowing into dry seedbeds. Faster developing winter cultivars would enable flowering at optimal times from later establishment dates (Hunt et al., 2019b), however commercial releases are 3 - 5 years away. In the meantime, growers continue to sow quick developing spring cultivars early and often dry hoping the breaking rains occur at the optimum time. This exposes crops to the risk of early germination and yield losses from low biomass accumulation and frost damage. Spring wheats are also unstable in flowering date and season to season variation in autumn temperatures associated with climate change are likely to exacerbate instability. In these scenarios management to slow down development within season could be advantageous to stabilise whole farm flowering dates and yield.

The horticultural industry uses tools other than sowing date that have not been explored in annual crops to manipulate the onset of flowering, budset, and maturation, including interventions such as defoliation, mechanical removal of reproductive organs, and chemical desiccation. Exogenous applications of hormones are known to regulate plant development, reproduction and floral initiation in winter cereals (Razumov, 1960; Barabas and Csepely, 1978; Pearce et al., 2013). Viticulturists routinely use the different time of pruning of vines as a way to manage the warming climate in a perennial crop and manage development. Grazing cereal crops with livestock delays flowering by about 1 day for every 4-5 days of grazing (Virgona et al., 2006), but it is difficult to graze commercial paddocks evenly enough to suitably adjust development in the whole paddock. A similar effect could be achieved by mowing and using the biomass for hay or silage, presenting a commercially feasible option provided yield is not reduced (Muldoon, 1985). Grazing of cereal crops is not recommended to occur past the onset of stem elongation, however this assumes crops are sown at optimal times. Here we evaluate the use of chemical or mechanical defoliants to prune the apex of early sown crops after the onset of stem elongation to "reset" flowering time and shift it to more optimum conditions in precocious crops. This differs from dual purpose recommendations and if successful would allow alignment of crop lifecycle without need for multiple cultivars and widen the sowing window by de-risking dry sowing and unknown germination times.

Methods

Experiments were conducted at five locations in South Australia. Three germination dates were targeted, defined here as time of sowing (TOS) 1, 2 and 3. The well adapted quick to mid-developing spring wheat Scepter was sown at all sites and either the quick winter Longsword at Minnipa, or the mid-quick developing Illabo at all other sites. TOS1 was the 15th April (+/- 2 days) which is optimal for winter cultivars in all environments. TOS2 was early to mid-May (Minnipa 7 May – Giles Corner 16 May) which is optimal for quick developing spring cultivars in most SA environments. TOS3 was the 5th June (+/- 3 days) which is considered too late for all cultivars. The Hart site had only an early and late planting date. Defoliation treatments of a chemical anionic acid and mechanical defoliation (using a mower to remove the emerging apex) treatment were imposed to Scepter (locally adapted fast spring cultivar) sown early (TOS1) when the crop reached Zadoks growth stage 31 – 32 (Terminal spikelet). This is known as the reset strategy.

Table 1. Mean annual, summer fallow (Nov-Mar) and growing season (Apr-Oct) rainfall from nearest Bureau of Meteorology weather station in comparison rainfall recorded at experimental sites for the relevant growing seasons.

Site	Station number & years of record	Mean Annual rainfall-mm	Mean Nov - Mar (2018 – 2019) rainfall-mm	Mean Apr – Oct (2019) rainfall-mm
Minnipa	18053 (1914-2019)	346	90 (39)	256 (216)
Cummins	18023 (1914-2019)	423	81 (43)	341 (319)
Loxton	24024 (1984-2019)	264	95 (70)	170 (93)
Giles Corner	23314 (1876-2019)	526	127 (97)	398 (267)
Hart	21007 (1897-2019)	405	108 (71)	328 (240)

All varieties were planted with adjusted seeding rates aiming for a target plant density of 150 plants/m^2. Ten millimetres of irrigation at sowing was applied to ensure even establishment at the first sowing times. The sites were managed for pest and disease throughout the season and fertilised with ? at optimal rates recommended for the each site. Plots were sown in six row 5 m plots at 22.8 cm row spacing. Measurements included, flowering time, biomass at maturity, harvest index, grain yield and components. Experiments were analysed individually using either ANOVA or mixed linear models (row:column experiments) and differences reported at the 95% level of confidence.

Results

Summer fallow rainfall (Nov – Mar) and growing season rainfall (GSR, Apr-Oct) were below average at all sites. The distribution of rainfall was slightly skewed towards later spring rainfall. Loxton received only 93 mm of GSR and experienced severe terminal drought stress. Frosts occurred during reproductive development at all sites, the most severe and frequent events being at Loxton (Table 2). During the optimal flowering period within each environment (early to mid-September) there were minimal frost events at Minnipa and Cummins, whereas Giles Corner and Loxton suffered 6 and 4 events respectively. There were few frosts during October at all sites. Heat events were most prominent at Minnipa, with 4 days above 32 °C in September and 10 days in October and a maximum of 39.9 °C reached in the same month.

Table 2. Number of days below 0 °C (frost), lowest recorded minimum temperature and number of days above 32 °C (heat stress), and highest recorded maximum temperature during August, September and October at all environments.

Site	Year	Cold stress events no of Days temperature <- 0 °C (Min Temperature)			Heat stress events no of days temperature > 32 °C (Max Temperature)		
		Aug	Sep	Oct	Aug	Sep	Oct
Minnipa	2019	0	0	0	1 (32)	4 (34.4)	10 (39.9)
Cummins	2019	4 (-0.8)	1 (-0.1)	0	0	0	7 (39.5)
Loxton	2019	8 (-3.2)	6 (-3.6)	0	0	0	9 (39.0)
Giles Corner	2019	8 (-1.9)	4 (-1.7)	1 (-0.1)	0	0	8 (38.4)
Hart	2019	5 (-2.5)	1 (-0.6)	0	0	1 (32)	9 (38.3)

Flowering dates of the quick to mid maturing spring cultivar sown in mid-April varied from 11 August at Hart to 6 September at Giles Corner (Table 3) and before optimal flowering periods at all sites (Table 3). The winter cultivar sown mid-April flowered 7 days later than the optimum flowering window at Minnipa, 4 days later at Cummins, 16 days later at Loxton, 1 day later at Giles Corner, and 8 days earlier at Hart. Apical pruning by mechanical defoliation had a significant effect on flowering time, but the chemical defoliation did not (not presented). The effect of mechanical defoliation ranged from 9 days delay in flowering date at Giles Corner to 18 days at Hart. The mean effect of defoliation was a 13 day delay in time to flower across all sites; however this only shifted flowering to be within the optimal flowering period (OFP) defined by Flohr et al. (2017) at Minnipa, and still too early at the other sites.

Table 3 Anthesis dates of the quick - mid (Q-M) cultivar Scepter across all sites in 2019 and in response to defoliation from the mid April germination date at all sites compared to controls.

Site	Q-M Spring flowering date	Defoliated Q-M Spring flowering date	Defoliation effect (days delayed)	Winter control flower date	Optimal flowering date#
Minnipa	14 Aug	25 Aug	-11	2 Sep*	25 Aug
Cummins	22 Aug	02 Sep	-11	24 Sep	18 Sep
Loxton	18 Aug	03 Sep	-17	25 Sep	9 Sep
Giles Corner	6 Sep	15 Sep	-9	27 Sep	26 Sep
Hart	11 Aug	29 Aug	-18	16 Sep	24 Sep

#Optimal flowering dates were derived for these locations from Flohr et al. (2017), *Longsword

Grain Yield responses

The reset spring strategy (mechanical defoliation of the early sown quick – mid spring cultivar) was the highest yielding treatment at Cummins and Minnipa, and similar to either the quick – mid spring sown at optimal or the highest yielding treatments at all other sites (Table 4). Importantly compared to the untreated quick - mid spring sown early the reset strategy yielded 1.5 t/ha higher at Cummins, 0.8 t/ha higher at Giles Corner, 0.4 higher at Hart and Minnipa, and not significantly different at Loxton. Compared to the practice of early sown winter wheat the mechanical reset strategy yielded 0.7 t/ha higher at Cummins, 0.5 t/ha higher at Hart, 0.4 t/ha higher at Minnipa, and was not significantly different at other sites. The yield of the reset strategy was greater than the late-planted quick- mid developing spring at all sites except Loxton which may be due to frost or terminal drought. Chemically defoliated treatments yielded similarly to the untreated early sown quick – mid spring cultivar in all environments.

Table 4. The yield response to management combinations of an early Quick – mid (Q-M) spring untreated and defoliated compared to a winter cultivar sown early, Q-M spring sown at optimum, and Q-M spring sown late at all locations. Letters that differ from each other within a site (column) are significantly different and shaded cells are equal highest yielding treatments

Management Combination			**Environment**				
SD	**Cultivar**	**Treatment**	**Cummins**	**Giles Corner**	**Loxton**	**Hart**	**Minnipa**
TOS1	Q-M Spring	Untreated	3.7d	5.1b	0.6bc	2.3b	2.7b
TOS1	Q-M Spring	Mech Defol	5.2a	5.9a	0.8ab	2.7a	3.1a
TOS1	Q-M Spring	Chem Defol	3.6d	5.0b	0.4c	2.2b	-
TOS1	Mid-Winter	Untreated	4.5c	5.5ab	1.1a	2.2b	2.7b
TOS2	Q-M Spring	Untreated	5.6b	5.3b	0.6bc	-	2.5b
TOS3	Q-M Spring	Untreated	4.3c	5.2b	1.0a	1.8c	2.1c
Environment			<0.001				
Management			0.003				
Environment x Management			<0.001				

Conclusion

The ability to speed up or slow down crop development within season opens new management possibilities not previously explored in annual grain crops. Apical pruning by defoliation and removal of main stem apices during early stem elongation was reliably able to reset development of precocious spring wheat and increase yield relative to untreated controls. Yields of reset spring wheat were comparable to early sown winter wheat, meaning growers may only require one cultivar and can still spread sowing dates substantially. The reset strategy differs from current dual purpose recommendations for grazing and needs to be fine-tuned and evaluated over sites and seasons, but if results are repeated, this approach would be transformative as it offers growers the ability to plant early, irrespective of seasonal break timing and then manipulate phenology to better match the season. The approach may not be suitable for the lower rainfall zones and alternative strategies must be pursued, such as faster developing winter wheats that will maximise biomass production but flower on time from both early and late germination. New management approaches such as this complement breeding programs and is potentially a relatively low cost adaptation tool for growers in a warming and drying climate. The strategy also offers an opportunity for barley growers or other crops that are yet to be experimented with. The strategy could also be used in more agro-ecological zones than winter wheat currently is because it doesn't have the same downside under late emergence.

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