Management of early sown wheat: soil water requirements for establishment

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Abstract
Following the release of new winter wheat cultivars in Australia, growers have been presented with the opportunity to sow wheat early, capitalising on early rainfall. The potential to sow winter wheats early without increasing frost risk may be an important tool for some growers where sowing programs are difficult to keep within optimal windows. However, the effect of early vegetative stress on these cultivars when sown early is not yet fully understood. Experiments were established at two sites in Victoria and one in South Australia in 2017 and 2018 to investigate the amount of soil water required to establish winter wheat cultivars early across different environments. Four establishment dates were targeted; 15 March, 1 April, 15 April and 1 May. We found that 10 mm was sufficient to allow germination and emergence in most soil types and carry plants through until winter. However, when planting in March on heavier soil types, at least 25 mm of rainfall and/or accessible soil water was required for successful establishment and to keep plants alive until late May and early June rainfall.

Key Words
Winter wheat, soil water, early sowing, vernalisation

Introduction
With the development of new winter wheat cultivars, early sowing opportunities (prior to April 25) may be taken by growers in low to medium rainfall zones in southern Australia, allowing an extension of sowing windows with the potential to increase whole farm yields (Hunt *et al*. 2019). The risk of yield loss from early flowering is substantially reduced when winter wheat cultivars are used due to their obligate vernalisation requirement maintaining stable flowering (Flohr *et al*. 2018). However, sowing early increases chances of crops being exposed to vegetative water stress and it is not known how this may impact yield of these new winter wheats, or what level of soil water is required to prevent plants dying before the onset of cooler temperatures and more reliable rains in winter. Understanding soil water requirements for successful germination and early growth will enable growers to make informed decisions around the risk of early sowing of winter wheats in their environment.

The aim of this study was to evaluate the response of three newly released winter wheat cultivars to post-sowing irrigation in the low to medium rainfall zones of Victoria and South Australia. This work is part of a larger project aiming to evaluate the suitability of additional newly released winter wheat cultivars to regions across the southern low to medium rainfall cropping zones (Hunt *et al*. 2019, Porker *et al.* 2019, Bruce *et al*. 2019, in these conference proceedings).

Methods
Three field sites were selected to represent different environments across the low to medium rainfall zones of the southern cropping region of Australia (Table 1). At each site, three newly released winter wheat cultivars; DS Bennett, LRPB Kittyhawk and Longsword, were sown at four times in a randomised split-split plot design with time of sowing as the main plot, irrigation rate (10, 25 or 50 mm of irrigation applied to press-wheel furrows using pressure compensating drip line) as the sub-plot and cultivar as the sub-sub plot. There were four replicates of each treatment. Soil samples to 1 m were taken prior to the first sowing time to estimate plant available water at each site. Four sowing times targeted dates of were 15 March, 1 April, 15 April and 1 May and actual sowing dates fell within five days of these targeted dates across all sites.

Measurements of plant establishment and grain yield were analysed individually using mixed linear models or across environment using ANOVA with, irrigation, cultivar, and sowing date as factors/fixed effects and block structure as random effects.

Table 1. Location of field sites, growing season rainfall (mm) and decile (in brackets), starting soil moisture (mm) and soil type for each site over two years.

Site	Horsham (VIC)	Birchip (VIC)	Loxton (SA)
2017 Soil type	Heavy clay	Sandy clay loam	Sand
2017 Starting soil moisture (mm)	118	167	162
2017 GSR (mm)	303 (5)	215 (4)	135 (2)
Previous crop	Lentil	Fallow	Field peas
2018 Soil type	Heavy clay	Clay	Sand
2018 starting soil moisture (mm)	45*	76	100
2018 GSR (mm)	226 (2)	138 (1)	92 (1)
Previous crop	Lentil	Fallow	Field peas

*stored at depth with dry soil at the surface

Results and Discussion

Establishment

The interaction between time of sowing, irrigation and environment (site) was significant (P=0.008). However, the sum of squares was relatively low compared to interactions of sowing time × environment, and environment × irrigation. Increasing water supply did not always increase establishment depending on environment and sowing date. In 2017; sowing during March followed by 10mm of irrigation resulted in lower plant establishment compared to 25 mm and 50 mm at Horsham however, this was not the case at Birchip and Loxton. The Birchip site was established on a long fallow, while the Loxton site was established on a sandy soil where 10 mm of rainfall was sufficient to achieve similar establishment to May planting dates. Follow up rainfall in early April 2017 at the sites also compensated for the greater evaporation rates from March sowing. However, there were large differences between environments. At late April/early May planting dates, plant establishment was similar across all irrigation rates within a site. While in most cases 10mm of irrigation was required for optimal establishment, the interaction between sowing date and environment (site) suggests that other factors such as temperature, soil type, evaporation and starting soil water may be equally or more important as irrigation for crop establishment from pre-April 20 planting dates.

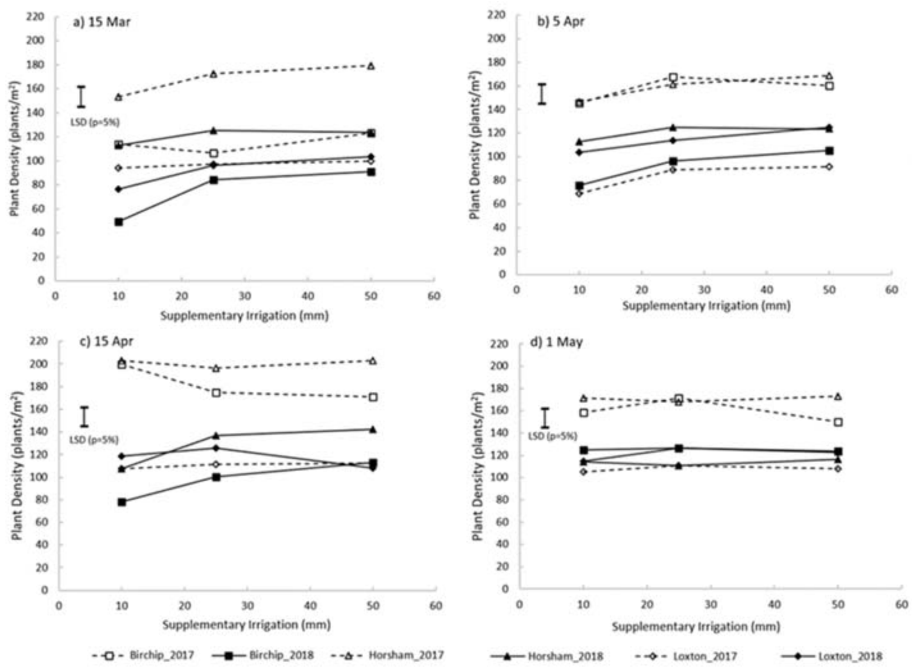

Figure 1. Established plant density (plants/m^2) at all sites targeting sowing dates of (a) 15 March , (b) 1 April, (c) 15 April and (d) 1 May across three water levels.

Plants that received only 10 mm of irrigation at the first time of sowing in 2018 suffered severe moisture stress as follow-up rainfall did not occur until early June. As a result, a large portion of emerged plants died at Horsham and plant establishment was lower at all sites. At Horsham, later rains resulted in a second emergence of seeds that had not germinated earlier. Although highly stressed, emerged plants at Loxton and

Birchip in 2018 were able to recover following rain in June. Applying 25 mm of irrigation improved establishment, however no further improvements were observed from irrigation above this. With the exception of Birchip in 2018 (10 mm at 15 March), all plant densities were greater than 50 plants/m^2. This is important as other experiments conducted at Yarrawonga and Loxton (Porker *et al.* 2019, this conference proceedings) have demonstrated there is no yield penalty from plant densities as low as 50 plants/m^2 compared to densities of 150 plants/m^2 when sowing early. Given the contrasting seasons, it was concluded that when sowing from mid-March to early-April, 10 mm was sufficient for crop establishment on sandy soil types such as Loxton, and 25 mm was sufficient on heavier soil types such as Horsham and Birchip. However, it should be noted that drip irrigation was used in these experiments and is not entirely reflective of respective rainfall events.

Yield

Grain yield was affected by a significant interaction between environment, time of sowing, cultivar and irrigation rate. However, this was largely driven by cultivar × time of sowing and environment × cultivar responses which have been discussed in greater detail in Porker *et al.* 2019 (this conference proceedings). Therefore, we have focused on the interaction between sowing time and irrigation within environment which reflects differences in soil type, starting soil water, temperature and rainfall patterns.

2017 and 2018 presented two very different seasons across SA and VIC. Yields in 2018 were much lower than in 2017 due to a late break and persistent dry conditions. For the 15 March sowing in 2017, yields were similar across all irrigation rates at all sites due to widespread, early and follow up rainfall across environments. At Birchip, available soil water at sowing was high due to being established on a long fallow. From the 15 March sowing in 2018 there was a small yield increase from irrigation above 10 mm at Loxton and Horsham, but a yield decrease at Birchip with irrigation above 10 mm.

At all sites in 2017, yields were similar across irrigation rates. This is likely due to good in-season rainfall following initial irrigation, reducing moisture stress following anthesis for grain fill. For the 1 May sowing in 2018, there was a yield increase with increasing irrigation rate at Birchip and Horsham (Figure 2). With later sowing there is a shorter time for growth throughout the season in suitable conditions, resulting in crops not having as long to utilize subsoil moisture as those that are sown earlier. Crops sown at 15 March sowing time hayed off earlier in 2018 than later sown treatments. This is likely due to the increased early water supply contributing to vegetative growth and leaf development rather than reproductive growth which could not be supported by subsoil moisture supplies used up earlier in the season from the earlier planting dates, where a yield reduction was found in some cases. The 1 April data (not presented) showed similar responses to the 15 March sowing date, and the 15 April data (not presented) similar to the 1 May sowing date.

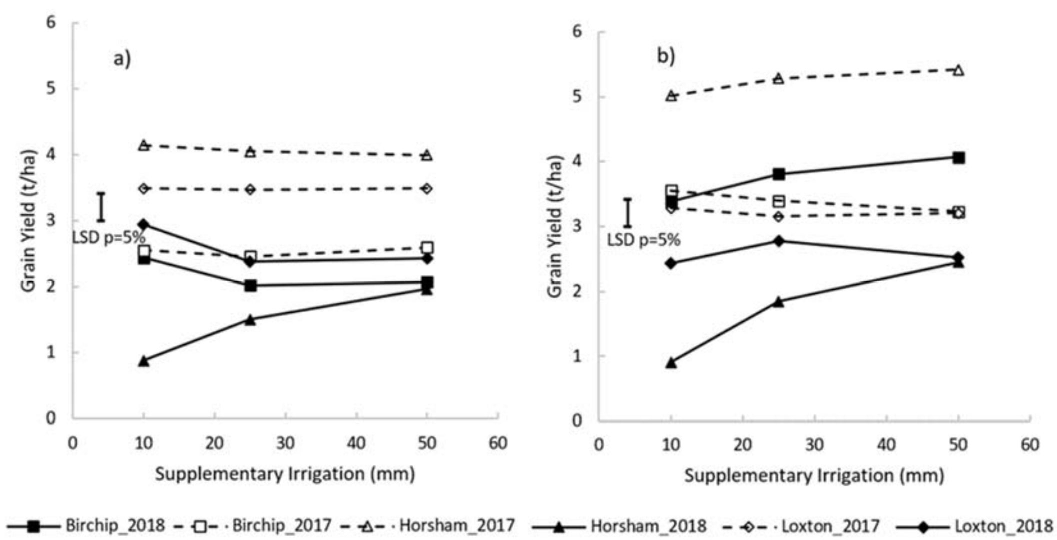

Figure 2. Mean grain yield (t/ha) averaged across cultivars at the 15 March (a) and 1 May (b) sowing times across different irrigation rates and environments. Note: Horsham 2018, 15 March 10 mm yield results are partly from secondary germination due to significant plant death following the first emergence.

It was somewhat unexpected to find a yield reduction due to irrigation in a dry year as was seen for early sowing dates at Birchip and Loxton and for the 50 mm treatment when sown late at Loxton in 2018. The early sown 10 mm treatment at Birchip in 2018 struggled to access the fallow moisture, and suffered significant vegetative drought stress, reducing early growth, but was able to preserve fallow water for use later in the season when yield is determined. Slower canopy development in the 10 mm irrigation treatment suggests less water use than the 25 mm and 50 mm treatments up until 29 July when canopy sizes became similar. This was supported by NDVI data from Birchip in 2018 showing that the 10 mm treatment of TOS1 had the highest NDVI later in the growing season due to lower water use early in a dry season (Figure 3).

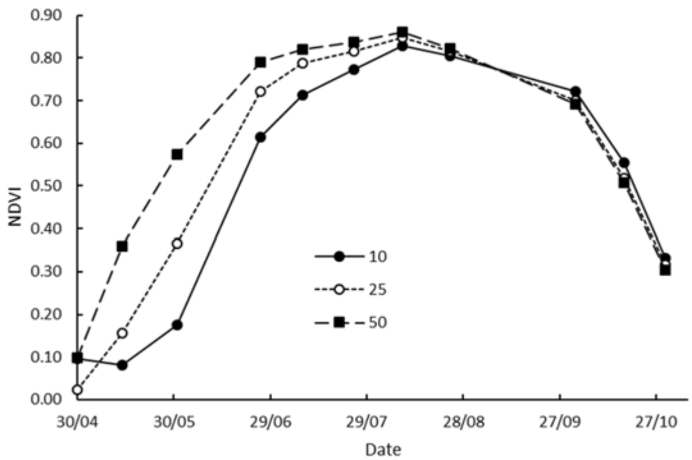

Figure 3. Mean NDVI of all cultivars at TOS1 with different irrigation rates at Birchip 2018

Conclusion

Based on the observations made from this data it can be concluded that 10 mm was sufficient for germination, emergence and survival until early June rain on most soil types across sowing times from 15 March to 1 May. However, when planting on 15 March on heavier soil types with no stored soil moisture near the surface, at least 25 mm of rainfall and/or accessible soil water was required for successful establishment and to keep plants alive until early June rainfall. Our data also show that establishing crops in March to early April can lead to inefficient use of water under hot and dry autumn conditions such as 2018. Higher rates of water supply in some circumstances resulted in lower yields. The preservation of water during early plant growth at depth is known to result in increased yields by retaining water following anthesis for contributions to grain fill (Dreccer et al. 2002). Deferring subsoil water use by crops, in the early sown 10 mm treatments in the case of this experiment, by restricted early growth was enough to cause a yield increase compared to 25 mm and 50 mm treatments sown on the same date in 2018.
With one of the hottest and driest autumns on record, 2018 provided conditions that tested the limits of how much water was required to successfully establish winter wheat early in autumn. The difference across environments with respect to soil type, temperature at sowing, stored moisture and rainfall all need to be considered and requires further evaluation.

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