Transformational agronomy by growing summer crops in winter: water productivity of dryland sorghum on the Liverpool Plains, NSW

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Abstract
Early sown sorghum is a viable alternative for the Liverpool Plains of NSW. It is currently unknown if the longer vegetative period created by sowing into sub-optimal soil temperatures could affect water productivity.
Water use was measured on an early (Agitator) and a late (MR Buster) maturing hybrid, sown in early and late spring and summer in 2018 and 2019 at 30, 60 (standard practice) and 120 thousand plants/ha.
Crops sown very early into cooler soil conditions had lower water use than those sown at early and normal sowing times. There was a significant impact of time of sowing on grain yield, which was seasonally dependent. Water productivity for MR Buster was higher when grown at 30,000 plants/ha compared to the standard density and higher density. For Agitator, earlier sowing reduced water productivity.
The potential of early sowing to increase yield and water productivity of sorghum needs assessment under additional seasons and environmental conditions.

Keywords
Water-use, early sowing, plant density

Introduction
Water is the most limiting factor in broadacre crop production in Australia. The demand for water by summer crops like sorghum is driven by the need to support reproductive growth in the peak heat periods of late December and January.
The Liverpool plains regions of NSW is considered one of the most favorable cropping regions in Australia. However, the combination of heat and moisture stress can still reduce yield potential. Farmers have various strategic and tactical decisions to adapt to variable weather including planting date, crop and cultivar choice (Hadebe 2017). On the Liverpool Plains the option to move the sowing date forward into early September, rather than the traditional November planting time is a viable one, which will likely impact on total water use and overall water use efficiency.
Total sorghum water use is primarily affected by growth stage and environmental demand (Assefa 2010). Water use increases as crop development approaches anthesis and declines as grain fill finalizes. Water stress at the sensitive reproductive and grain filling stages can be especially damaging (Kramer 1983).
Earlier planting increases opportunities for double cropping and extends the time to refill the soil water profile. However, these potential benefits could be negated if total water use increases and water use efficiency is reduced.

Methods
Two dryland experiments were sown at the Liverpool Plains Field Station, Breeza in 2018-19 and 2019-20. Three factors were included; time of sowing (TOS), plant population and hybrid (Table 1). Sowing date was determined by soil temperature, with targets of 12, 14-16 and 18°C. These soil temperatures were defined as very early (TOS 1), early (TOS 2) and normal (TOS 3) sowing times. Four plant densities were targeted 30000, 60000, 90000 and 120000 plants/ha. All experiments were sown using a precision planter and had 3 replicates. TOS (3 levels), plant population (4 levels) and hybrid (6 levels) were randomised using a split-split plot design within each experiment.
A subset of treatments; TOS (3 levels), two hybrids; Agitator and MR Buster and three plant densities 30000, 60000 (MR Buster only) and 120000 plants/ha were selected for measuring water with a neutron moisture

meter. Access tubes were installed at emergence in the selected plots, in the sorghum row. Soil water storage in the profile was measured at emergence, six leaf, flag leaf, flowering and physiological maturity.
Plots were hand and machine harvested to determine grain yield. Hand harvested plants were threshed to determine grain yield and quality, while machine harvested plots were subsampled to determine grain quality traits.

Table 1 Site characteristics for sorghum experiments sown in 2018-20 at Breeza, NSW (Lat/ Long: S31⁰ 10.8740, E150⁰ 25.2730).

Trial site and TOS	Sowing date(s)	Soil temp. at 8am# (°C)	Plant Population (plants/ha)	Hybrids	In-crop rainfall (mm)	Irrigation* (mm)
2018-19						
1	6th Sept	11.2	30,000 60,000 90,000 120,000	MR Buster, MR Apollo, MR Taurus, Agitator, Cracka, HGS114, A66, G33	222.9	NA
2	17th Sept	10.3			222.9	NA
3	23rd Oct	18.8			170	NA
2019-20						
1	11th Sept	12.1	30,000 60,000 90,000 120,000	A66, Agitator, Cracka, HGS114, MR Taurus, MR Bazley, MR Buster, Sentinel IG	307	Pre-watered In-crop -19th Dec
2	8th Oct	17.8			296	Pre-watered In-crop -19th Dec
3	29th Oct	21.2			402	Pre-watered In-crop -19th Dec

#Average soil temperature (°C) at 8am at sowing depth for seven days after sowing. * irrigation applications were applied as flood to the field which was on raised beds only as a salvage due to moisture stress.

Results

Plant development and grain yield

Earlier sowing time delayed anthesis. In 2018-19, plots in TOS 1 required 95 days to reach 50% anthesis, while those in TOS 2 and TOS 3 sowing times required 85 and 69 days respectively (data not shown).
In 2018-19 grain yields were higher from the earlier sowing times (TOS 1 & 2) compared to the normal sowing time (TOS 3). In 2019-20, drought induced moisture stress occurred as only 100 mm of rainfall fell between sowing and mid- December. This caused visual plant stress requiring a salvage irrigation. As a result, yields for TOS 1 and TOS 2 were reduced compared to TOS 3.
In 2018-19 grain yield declined as photothermal quotient (ptq) declined while in the following season the opposite occurred; higher yields from lower photothermal quotient (Figure 1). This was likely caused by moisture stress overriding the response to radiation and thermal temperature.

(a) **(b)**

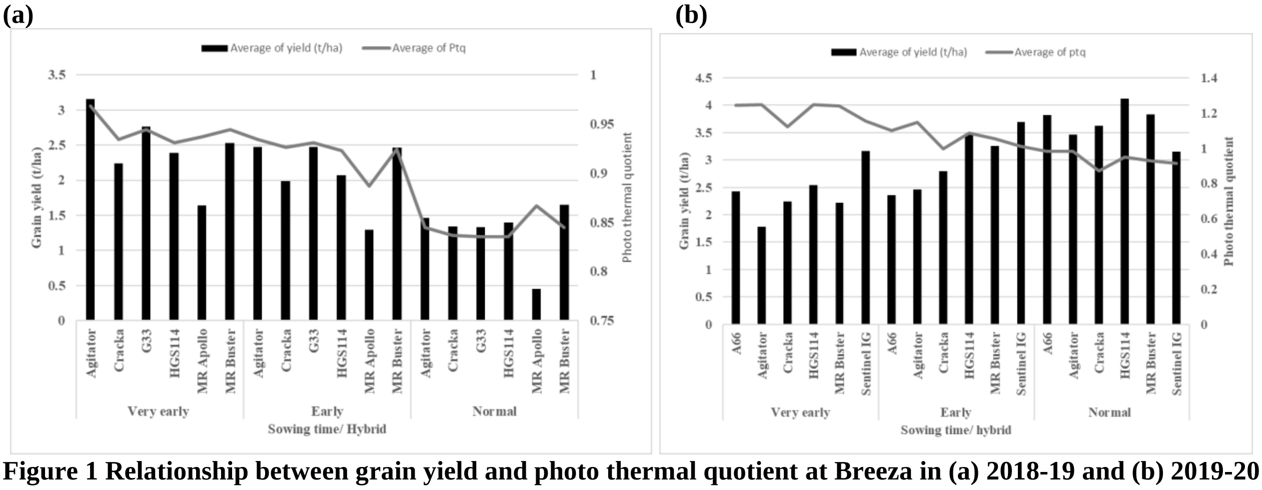

Figure 1 Relationship between grain yield and photo thermal quotient at Breeza in (a) 2018-19 and (b) 2019-20

Total water use

In 2018-19 the early sowing time (TOS 2) used more water than TOS 1 and TOS 3 (Table 2). There was no difference in the total water use between hybrids even though they have different maturities. In 2019-20 total water use was higher than 2018-19 (Table 2). The crop used more water in TOS 2 and TOS 3 than the very early sowing time (TOS 1). Sowing at higher soil temperatures resulted in greater water use. The distribution of rainfall during 2019-20 had a large impact on this, with significant rain falling post anthesis for TOS 1 and TOS 2. Late rain benefited the normal sowing time in this season.

Table 2: Total water use (mm) at Breeza 2018-20 for MR Buster (averaged across populations)

Year/ Sowing time	Very early (TOS 1)	Early (TOS 2)	Normal (TOS 3)
2018-19	367.0	443.0	359.0
2019-20	482.5	566.8	597.6

Ls.d: 2018-19: 44, 2019-20: 39.9

Water use efficiency

In 2018-19 water use efficiency was higher in TOS 1 and TOS 2 when crops were sown into cooler soil (11.2 and 10.3 °C) (Table 3).

Table 3: Water use efficiency (kg/ha/mm) at Breeza 2018-19 (averaged across populations and hybrids). There were no significant interaction effects.

Sowing time	WUE (kg/ha/mm)
Very early (TOS 1)	6.51
Early (TOS 2)	5.68
Normal (TOS 3)	2.44

L.S.D: 2018-19: 2.25

In 2019-20 there was an interaction between plant densities and sowing times. Water use efficiency declined as plant density increased for both TOS 1 and 2 (Figure 2). There was no difference between population densities for TOS 3 which was sown into higher soil temperature. MR Buster had a higher water use efficiency than Agitator in this season.

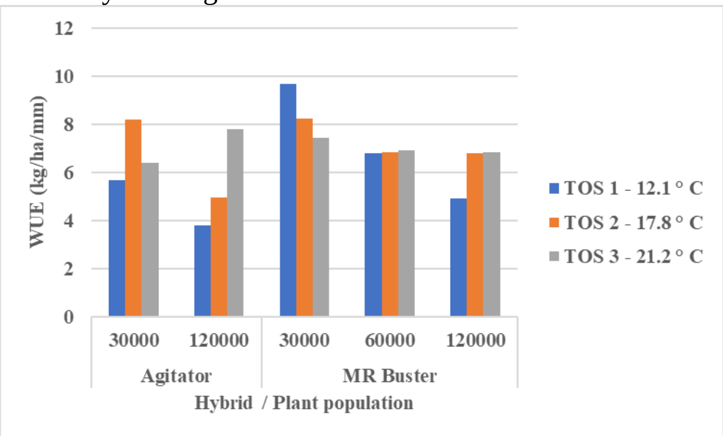

Figure 2: Water use efficiency response to varying sowing time at Breeza 2019-20 (LSD = 2.61 kg/ha/mm)

Conclusion

Sowing sorghum into cooler soil affects plant development, grain yield, water use and water productivity. Earlier sowing delayed anthesis by as much as 25 days in the 2018-19 season.
Yield response to sowing time was affected by seasonal rainfall distribution. In the first season grain yields were greater from the earlier sowing times. However, the reverse occurred in the following season.
Total water use was affected by time of sowing, however the effect varied between seasons.
Sowing sorghum earlier (into cooler soils) can improve water use efficiency, as demonstrated in 2018-19 season. In the following season water use efficiency declined as plant population densities increased.
Crop responses to sowing time, population and hybrid were not consistent across both seasons. This suggests the need for further field data to improve our understanding of early sown sorghum.

References

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