Transformational agronomy by growing summer crops in winter: northern NSW

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Abstract
Grain sorghum yield is often reduced by heat and water stress during critical growth stages around anthesis when planted in the traditional sowing window. Sorghum sown during late winter or early spring can flower before these stresses develop, though reduced plant establishments due to sub optimal soil temperatures and the likelihood of frost damage need to be managed.
Two years of experiments at Mungindi, Moree and the Liverpool Plains in Northern NSW compared sowing time effect on plant establishment, date of anthesis and grain yield.
Sorghum can be established in sub-optimal temperatures (<16°C) if seedbed moisture is available but losses of 10-30% need to be factored into sowing rates. The overlap between flowering and heat stress was minimised by 'winter' or early spring sowing. Grain yield was maintained or improved by planting earlier compared to traditional sowing times.

Keywords
Grain yield, quality, plant establishment, anthesis

Introduction
Growing a summer crop in late winter/ early spring could provide significant benefits in the water limited and variable climates of Northern NSW. These benefits include increased yields, improved production stability, increased ground cover and fallow moisture storage, and a new rotation for the more marginal growing regions.
Grain sorghum may allow a new crop option for the north west of NSW if reliable production can be demonstrated. Whilst grain sorghum is largely considered drought tolerant and thus should have adaptation to water limited environments (Assefa 2010) the combination of heat and moisture stress is challenging. To enable this, sorghum anthesis and grain fill would need to be moved from periods of high likelihood of heat and moisture stress; this is late December and January for the northern NSW region.
Traditional sorghum production areas in north east NSW (i.e. east of the Newell highway and the Liverpool Plains) would also benefit from late winter/ early spring sowing when a double crop could be planted after a short fallow, increasing crop rotation intensity.
To achieve these goals, sorghum must be able to germinate, emerge and establish in soil temperatures that are cooler than the current sowing window of 16-18 °C whilst avoiding frost damage. Sorghum is a C_4 plant which inherently has sensitivity to temperatures below 15 °C and can thus display detrimental effects on nearly all physiological and developmental processes under chilling conditions (Schaffasz 2019). Furthermore, the crop needs to reach physiological maturity faster than the traditional crop sowing window to allow a longer period for the soil profile to refill during summer.

Methods
Three factors were included in each experiment. Namely, time of sowing (TOS), plant population and hybrid. Actual sowing date was determined by soil temperature, with targets of 12, 14-16 and 18°C for the north eastern sites and 12 and 18°C for the north western sites. These target dates were termed as very early, early and normal sowing times. Four plant population densities were targeted, 3, 6, 9 and 12 plants/m^2. Experiments were sown using a precision planter and had 3 replicates. TOS (2-3 levels), plant population densities (4 levels) and hybrid (6-10 levels) were randomised using a split-split plot design within each experiment.
In-crop measurements reported here include plant establishment, anthesis date and grain yield. Plant emergence was measured weekly until plant populations became stable and any deaths recorded.
At physiological maturity eight plants from each plot were cut and dried to a constant weight to determine total biomass. Panicles were cut and hand threshed to determine grain yield.

North western sites

Experiments were sown at two locations near Mungindi in 2019-20 (Table 1). Nine hybrids and two TOS (very early and a normal sowing time) were included at each site. The equivalent of 33 mm of rainfall was applied post sowing to generate a planting opportunity despite drought. Only plant establishment data is available for "Bullawarrie" and "Morialta", as the experiments failed due to no in-crop rainfall.

North eastern sites

Experiments were sown at Moree in 2018-19 and Breeza in 2018-19 and 2019-20 seasons. Three sowing times were included at each site, a very early, early and a normal sowing time. Eight to ten hybrids were included, depending on the field layout (Table 1).

Table 1 Site characteristics for sorghum experiments sown during the 2018-20 season across Northern NSW.

Trial site and TOS	Sowing date(s)	Target plant density (plants/m^2)	Hybrids	Soil temp. at 8am[#] (°C)	In-crop rainfall (mm)	Irrigation[b] (mm)
2018-19						
"Ponjola" Moree, NSW (Lat/ Long: S29 11.622, E 150 03.500)						
1	7th & 8th Aug	3, 6, 9, 12	MR Buster, MR Apollo, MR Taurus, Agitator, Cracka, HGS114, A66, G33	12.3	199.7	PS-33*
2	11 & 12th Sept			17.1	153.2	NA
3	27th Sept			18.9	153.2	NA
"LPFS" Breeza, NSW (Lat/ Long: S31° 10.8740, E150° 25.2730)						
1	6th Sept	3, 6, 9, 12	MR Buster, MR Apollo, MR Taurus, Agitator, Cracka, HGS114, A66, G33	11.2	222.9	NA
2	17th Sept			10.3	222.9	NA
3	23rd Oct			18.8	170	NA
2019-20						
"Bullawarrie" Mungindi, QLD (Lat/ Long: S28 51.7550, E 148 46.320)						
1	22nd & 23rd July	3, 6, 9, 12	A66, A75, Agitator, Cracka, HGS114, MR Taurus, MR Buster, MR Bazley, Sentinel IG	9.3	10	PS - 33* PE – 33*
2	2nd & 3rd Sept			14.1	10	PS – 33*
"Morialta" Mungindi, NSW (Lat/ Long: S29 17.3130, E 149 07.970)						
1	30th July	3, 6, 9, 12	A66, A75, Agitator, Cracka, HGS114, MR Taurus, MR Buster, MR Bazley, Sentinel IG	4.7	12	PS - 33* PE – 33*
2	10th Sept			6.4	12	PS – 33*
"LPFS" Breeza, NSW (Lat/ Long: S31° 10.8740, E150° 25.2730)						
1	11th Sept	3, 6, 9, 12	A66, Agitator, Cracka, HGS114, MR Taurus, MR Bazley, MR Buster, Sentinel IG	12.1	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. * Bore water was applied post sowing using dripper lines to ensure even establishment due to dry seedbed moisture conditions. Additional in-crop watering was applied using the same method. [b] – PS = post sowing, PE = post emergence.

Results

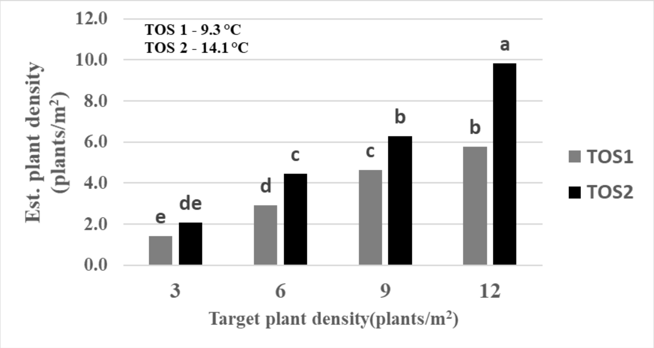
Plant establishment

(a) North western sites

In 2019-20 sites were irrigated post sowing to ensure plant emergence due to drought conditions. Plants emerged but no in-crop rain was received. Emergence was recorded 22 days after sowing at "Bullawarrie" and 29 days at "Morialta" for TOS 1. Average 8 am soil temperatures were 4.7 °C at seeding depth for the 7 days post TOS 1 at "Morialta". Emergence was quicker for TOS 2; 15 and 16 days respectively for "Bullawarrie" and "Morialta", even though soil temperatures were still cold (6.4 ° C) at "Morialta". This shows sorghum can establish in suboptimal temperatures but requires an extended period of germination and emergence.

Plant establishment was improved by the later sowing (TOS 2) at both sites for all densities except the 3 plants/m^2 (Figure 1). Very early sowing still achieved a commercial plant population under sub-optimal soil temperatures. However; establishment losses were on average 50% from the very early sowing at "Morialta" and only 25% from the normal sowing (data not shown). An increase in the rate of seed sown in the very early sowing (TOS 1) was required to achieve similar establishment to the normal sowing (TOS 2).

(a) (b)



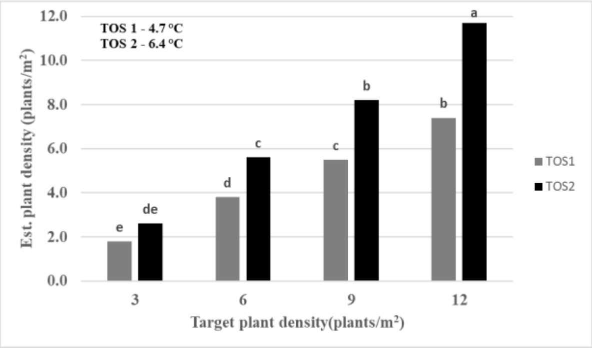


Figure 1: Sorghum established plant density compared to target plant density (averaged across hybrids) at "Bullawarrie" (a) and "Morialta" (b) Mungindi 2019/20 for very early (TOS 1) and normal (TOS 2) sowing times. (average soil temperature for 8 am EST for 7 days post sowing inset). Treatments without a common letter were significantly different at the 5% level.

(b) North eastern sites

Plant establishment improved as time of sowing was delayed to warmer soil temperatures (Table 2). The plant populations achieved from TOS 1 (sown in early September - Table 1) illustrates that establishment in late winter/ early spring when soil temperatures were <12 ° C is acceptable.

Table 2: Plant establishment at Breeza in 2019-20. There was a significant TOS main effect (P<0.001). Predictions are averaged across all hybrids and target plant populations as the TOS × Hybrid and TOS × Target plant population interaction effects were non-significant. (LSD =0.37)

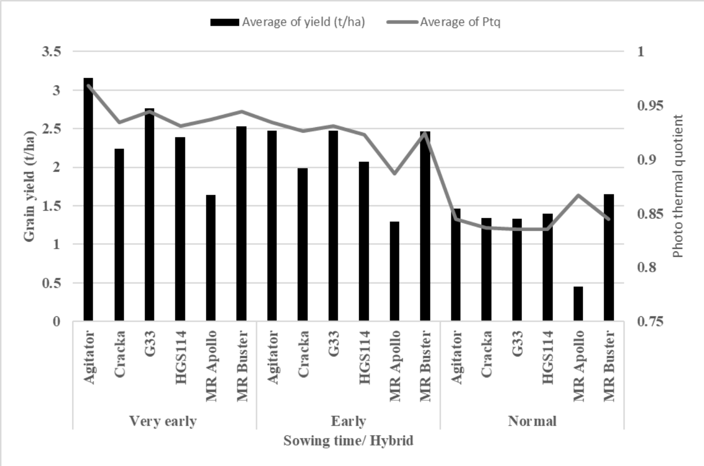
TOS/ Target plant population	Av. soil temp. at 8am for 7 days post sowing(°C)	Plant establishment (plants m^{-2})
TOS 1	12.1	6.74
TOS 2	17.8	7.92
TOS 3	21.2	8.35

Effect on time of sowing on anthesis date and biomass production

Earlier sowing resulted in an extended emergence-flowering period; for example, at Moree TOS 1 required 106 days to reach 50% anthesis (averaged across hybrids). TOS 2 – 82 and TOS 3- 75 days respectively. Earlier sowing caused a larger spread in maturity differences between hybrids. In the very early sowing, the slowest hybrid, MR Apollo flowered at 115 days, and the quickest hybrid, Agitator, 99 days. In contrast in the normal sowing time (TOS 3) MR Apollo flowered in 81 days and Agitator 70 days (data not shown). Very early sowing (TOS 1) advanced the anthesis window for all hybrids by around three weeks compared to sowing at the recommended soil temperature (TOS 3). This meant flowering was completed prior to the onset of very high temperatures at the beginning of December (data not shown).

Grain yield

Grain yields at Moree and Breeza in 2018-19 were higher from the earlier sowing time. This response for improved yield with earlier sowing was consistent across almost all hybrids at both sites (data not shown). One possible explanation is the correlation between grain yield and high photo thermal quotient (Figure 2).



L.s.d: TOS 1 0.57, TOS 2 0.49 and TOS 3 0.29.

Figure 2 Predictions of grain yield at Breeza 2018-19 and the relationship with photo thermal quotient. There was a significant TOS x hybrid effect. Predictions are averaged across target plant populations.

In the drier 2019-20 season grain yields were highest from the normal sowing time (data not shown). The season commenced in drought but finished with late in-crop rainfall which provided an additional 100 mm to the normal sowing time compared to TOS 1 and 2 (Table 1).

Conclusion

There are significant opportunities to move the traditional sowing window for grain sorghum earlier. In Mungindi and Moree this means commencing sowing in the last month of winter; August and as early as September on the Liverpool Plains. The decision to commence early sowing should always be based on rising soil temperatures and adequate soil moisture.
Early sowing still brings an inherent higher risk of plant death due to frost, but in the two experimental years this damage has been minimal (<10% plants). However, conditions for plant death are still not well defined. A reduction in plant establishment was measured from the early times of sowing compared with the normal sowing time. Increasing planting rates can compensate for these losses but also incur additional seed costs. Anthesis date is moved earlier by early sowing, resulting in less exposure to the critical periods of heat. Early sowing caused a larger spread in maturity differences between hybrids. Grain yields were improved or maintained by earlier sowing except in the 2019-20 season when drought severely stressed the early sowing.

References

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