Dryland and irrigated winter-sown sorghum

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Take home messages

- Winter sowing sorghum didn't penalise yields in eight trials sites from Liverpool plains to Central Queensland and across two seasons
- In dryland cropping, winter sown sorghum provides additional sowing opportunities, reduces the chances of heat stress, and increases the chances of double cropping a winter crop
- In irrigated cropping, ratooned winter sown sorghum can compete with cotton on profits and is less risky
- Commercially available hybrids can successfully germinate and emerge in cooler soils than previously recommended, though the seed must be tested for vigour at low temperatures
- Sorghum seedlings can withstand mild frost, though so far, we haven't been able to frost kill a crop, meaning that frost risk is unknown.

Background

Water stress and extreme heat at flowering are common stresses limiting yield in sorghum across the Northern Grains Region. Earlier sowing of sorghum could avoid heat and water stress at flowering. However earlier sowing or winter sowing of sorghum in southern Queensland requires the crop to be sown into soil moisture in cold soils.

Dryland farmers are already successfully sowing maize and sorghum earlier than recommended, though the benefits for yield and the cropping system and the likely risks are not known. Previous research by Muchow, et al., (1994) identified that winter sown sorghum crops show high yield potentials with increased frost risk and a larger canopy increasing water stress risk. However, these risks require re-evaluation because frost risk thresholds (thresholds were assumed in previous research) are unknown and modern hybrids have a smaller canopy.

In irrigated systems, sorghum is a profitable option when irrigation water is limited, though it is often assumed to be a less profitable option than cotton in fully irrigated systems. Winter-sowing and opportunistically ratooning sorghum allows growers to manage risk when water supply is limiting at the beginning of the season and intensify production and profits if rainfall is greater than expected.

Previous research shows that ratooned irrigated sorghum crops yield 80% of the sown crop yield on average (Gerik et al., 1990). Growers in Central Queensland successfully ratoon irrigated sorghum crops, though questions remain on the suitability of the system in southern regions and crop sequences.

Here we report on irrigated and dryland trials conducted by UQ-QAAFI in the 2018-2019 seasons. This series of trials is part of the multi-environment sorghum agronomy experiment in collaboration with DAFQ and NSW DPI. The experiment was designed to develop a data set to support the present trend in advancing sowing times of sorghum and assess potential benefits and risks from adopting the strategy at the crop and cropping system levels.

Trial details

Two trials were sown in the 2018-2019 season at Surat and Warra, Qld. Trials included three times of sowing, four plant populations and nine commercial hybrids (Table 1). In addition, after the harvest of the second time of sowing at Surat, the crop residues were mulched, fertilised, irrigated and allowed to ratoon into a second harvest. A third time of sowing occurred at the same time when sowing 2 was ratooned (Table 1). This allowed us to also compare the yield of the ratooned sorghum crop with the yield of a sown crop.

Table 1. Winter-sown sorghum agronomy trial locations and treatments

Time of sowing (TOS)	Sowing date	Target plant population (pl/m^2)	Hybrids
"Austin Downs" Surat, Qld (irrigated)		3, 6, 9, 12	MR Buster, MR Apollo, MR Taurus, Agitator, Cracker, HGS 114, A66, G33, G44
1	8th August 2018		
2	28th August 2018 & ratooned		
3	24th January 2019		
"Wywurrie", Warra, Qld (dryland)			
1	27th July 2018		
2	19th October 2018		
3	9th November 2018		

Results and discussion

Optimum flowering windows

Crop growth conditions around flowering are important in determining final grain number and grain yield. At flowering, grain number can be reduced by temperature extremes, both heat and chilling (i.e. cold but non-freezing temperatures). Analyses of long-term climate records (see CliMate App), can be used to quantify the likelihood of these stresses around flowering and identify ideal flowering windows.

For example, Figure 1A shows that chilling or heat stress temperatures are least likely in narrow and regionally specific windows during spring and autumn. These windows have a lower likelihood of heat (>38°C) and chilling (<13°C) events in a 10-day period corresponding to the sensitive flowering phase. However, the impacts of extreme temperatures on yield depend on duration of the heat/chilling exposure, crop water status and cultivar. Research on the relationships between extreme temperatures and the yield of early sown sorghum will continue throughout the GRDC funded project "Optimising Sorghum Agronomy".

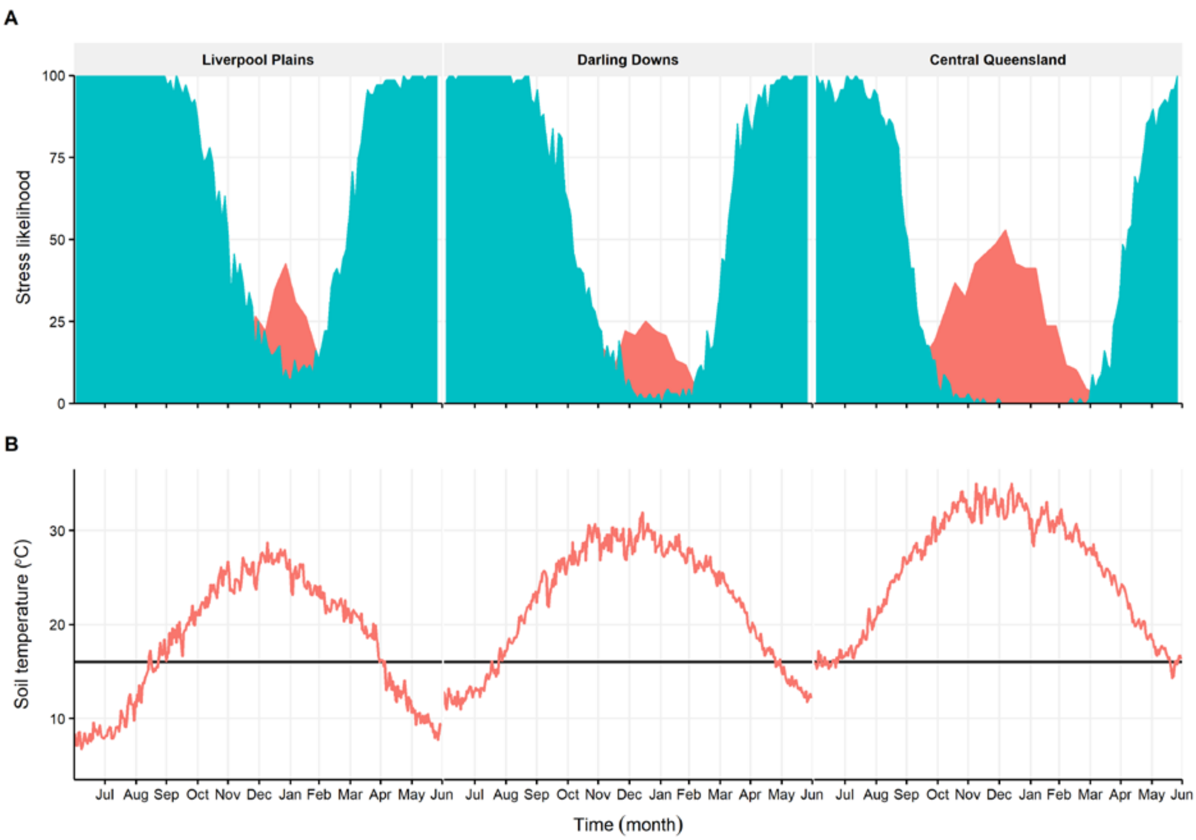

Figure 1. The likelihood or percentage of seasons exposed to heat (>38°C; **red**) or chilling (<13°C; **blue**) during a 10-day temperature sensitive period around flowering (A); and (B) the mean 9:00 am soil temperature measured at 50 mm depth in three sorghum growing regions, the Liverpool Plains, Darling Downs and Central Queensland. The horizontal line in Figure 3B shows the recommended minimum seeding depth temperature threshold for sorghum. (Note: 9:00am soil temperatures are shown because high quality long-term data for the conventional 8:00 am or minimum daily 100 mm deep soil temperatures were not available).

Targeting optimum flowering windows

The easiest way for growers to move the flowering window is to plant at a different time to their standard sowing time or to select a quicker maturity hybrid. As there is limited variation in maturity type among the commercial hybrids, moving the sowing window is the more effective option. This means sowing sorghum crops much earlier than normal, potentially moving sowing into the months of July and August depending on local climate. Soil temperatures during this period are cooler than the recommended (>16-18°C measured at sowing depth during the coolest period of the day or 8:00am; Figure 1B). Long-term trends show that July to August soil temperatures are coldest in the southern regions of Darling Downs and Liverpool Plains. However, time of sowing decisions require information on each field because of varying weather, topography, soil type, water content and ground cover, all of which strongly influence seedbed temperature.

Regardless of the sowing time, achieving rapid and uniform crop establishment is also required to realise yield potential. The decision on sowing time will then need to evaluate the trade-off between likely benefits of reducing heat stress around flowering, with the higher risk of early frost damage, higher establishment losses and potential for less even crop canopy uniformity.

Temperature effects on sorghum germination in 2018-2019

Planting sorghum into moist soils at extremely low or high temperatures can reduce crop establishment and reduce crop uniformity. Crop establishment is the result of several distinct plant development stages including seed germination, emergence, root proliferation and leaf growth. Here we studied the impact of extreme temperatures on the germination for a range of commercial sorghum hybrids in the lab.

Results showed that the lowest and highest observed seedbed temperatures from Figure 1B, reduced the proportion of sorghum seeds that successfully germinated in the lab (Figure 2).

Eight of the ten most widely grown sorghum hybrids showed germination values greater than 90%, when incubated with ideal moisture and at constant temperatures between 13 and 32.1°C (Figure 2). At 9.4°C, two of the ten tested hybrid seedlots still showed germination values larger than 90%.

Higher temperatures (≥34.9°C) reduced the germination of five out of the ten tested seedlots, yet three hybrids showed germination rates greater than 90% at extreme hot temperatures (39.5°C).

In these experiments, seeds were exposed to constant high temperatures for multiple days, whereas in the field, seedbed temperatures fluctuate diurnally. Maximum daily seedbed temperatures of 45°C were recorded during the 2018-2019 sorghum agronomy trial at Emerald, though those temperatures only exceeded the high thresholds for a short period each day (< 1 hour).

Seed production, storage, handling, seed treatment and genetics will all determine the germination rate for each hybrid-seedlot. Therefore, germination must be evaluated every year for each hybrid-seedlot. Understanding the drivers for low germination in Australian germplasm remains a priority research question.

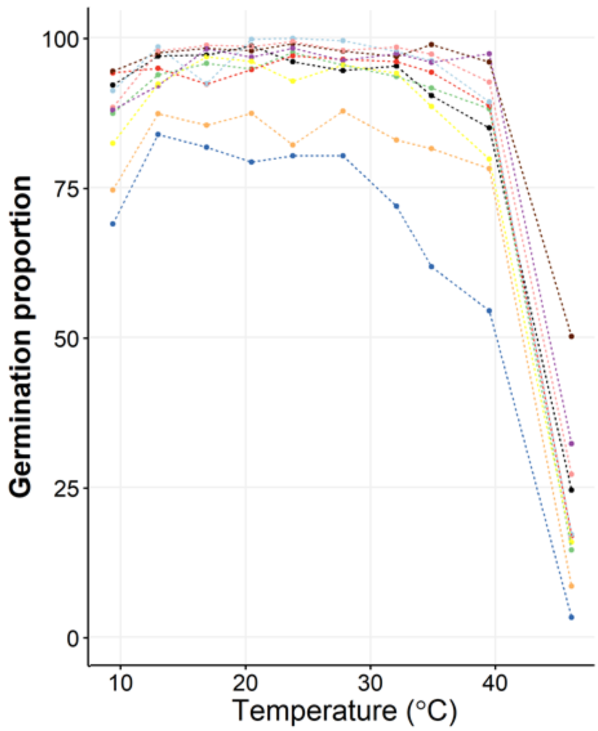

Figure 2. The proportion of sorghum seeds that successfully germinated when incubated at constant temperatures. Each colour represents one hybrid seedlot but they are not identified as the experiment doesn't differentiate if the result is due to genetic, seed production or storage factors.

2018-2019 temperature effects on predicted time required for successful sorghum germination

Low temperatures delay the period from sowing to germination and emergence. Therefore, quantifying the number of growing degree days is important. Growing degree days (GDD) are a measure of the accumulation heat and are used to predict plant development. GDD = ∑(Tmax – Tmin)/2 – Tbase. Tmax and Tmin are the daily maximum and minimum temperatures. Tbase is a crop specific minimum temperature for development. Here we estimated the required number of cumulative heat units for ten commercial hybrid seedlots under a controlled temperature environment. The results show that the first 10% of seeds germinate with 5 days but it took 9 days to achieve >90% germination at Surat in 2018 (Figure. 3). Results also show that germination time is similar across diverse sites on some dates, but germination timing is also highly variable for different sowing dates at any site (Figure. 3).

This means that July-August soil temperatures ≥9.4°C do not limit germination of commercially available sorghum hybrid-seedlots. However, germination will take a long time and will be spread over several days, meaning that the seedbed must remain moist for at least 9 days for successful germination and longer for emergence.

Investigations into the impacts of low seedbed temperatures on emergence continue in 2019-2020 through the GRDC funded project "Optimising Sorghum Agronomy".

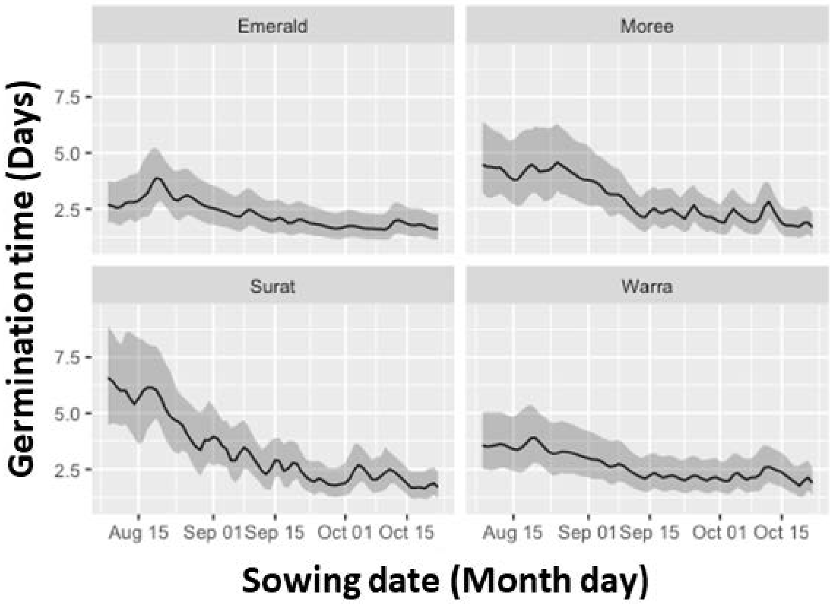

Figure 3. The predicted number of days from sowing until germination for sowing dates between 1st August and November 2018 based on seedbed temperatures recorded at four on-farm trial sites. Black line shows 50% seed germination and the grey shading shows the spread from 10 to 90% germinated seeds. (Note: data is for seed germination and not for crop emergence which will take far longer)

Climatic conditions for 2018-2019 trials

The 8:00am seedbed temperature at Surat for sowing time one was 8°C and it emerged 20 days later with seedbed temperatures of 10°C. Seedlings survived two mild frosts (~0°C) in late August and mid-September (Figure 1C). The earliest flowering hybrids in the first time of sowing had the highest photo-thermal quotient during flowering, meaning that growth and yield formation potential was greatest (Figure 4A). Flowering time of the latest flowering hybrids in the first time of sowing overlapped with the earliest flowering hybrids for the second time of sowing, meaning that combinations of hybrid and sowing time are required to target flowering (Figure 4A). Water was sufficiently available for all treatments, except irrigation ran out before time of sowing three finished flowering (Figure 4B). Maximum temperatures were high for all sowing times (Figure 4C).

Seedbed temperatures at 8:00 am measured at sowing depth (75mm) for the first time of sowing were 12°C and seed germinated 2 days later on the 30th July. Soil temperatures decreased to 10°C and seedlings emerged between 8 and 17th August. The first time of sowing at Warra had four consecutive frost days with minimum daily temperatures of 0, -4, -5 and -2°C without seedling death (Figure 5C). Pre-flowering rainfalls prevented water stress at flowering for time of sowing one and two, but time of sowing three was water stressed at flowering (Figure 5B). High temperatures occurred during flowering for all three sowing times (Figure 5C).

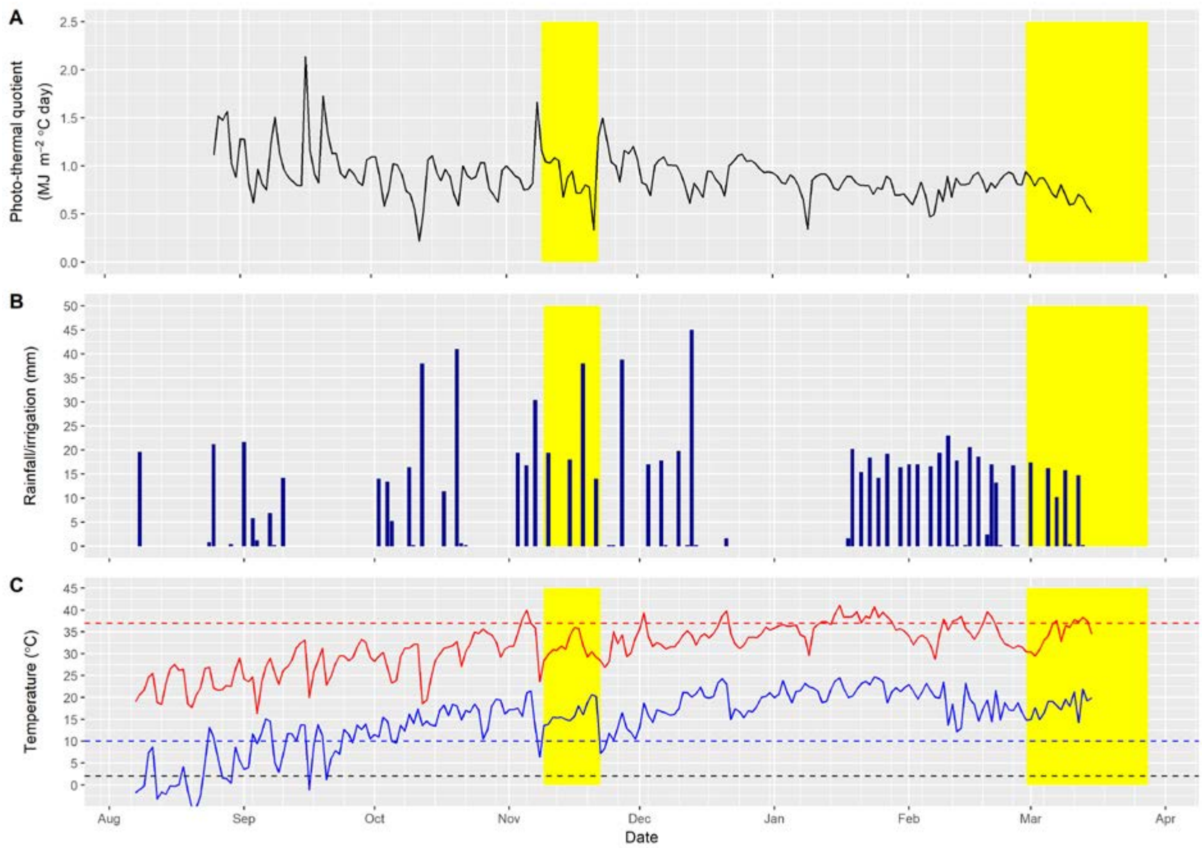

Figure 4. Photothermal quotient (A), rainfall (B) and ambient temperatures (C) at Surat, Qld for the 2018-2019 summer cropping season. The two yellow rectangles indicate the overlapping flowering timing for the 8th and 28th August 2018 sowing dates and 24th January and ratoon crop flowering dates, respectively. Solid blue and red lines represent daily maximum and minimum temperatures, respectively. Dashed horizontal represent the reported minimum (blue) and maximum (red) temperatures stress thresholds at flowering and frost (black).

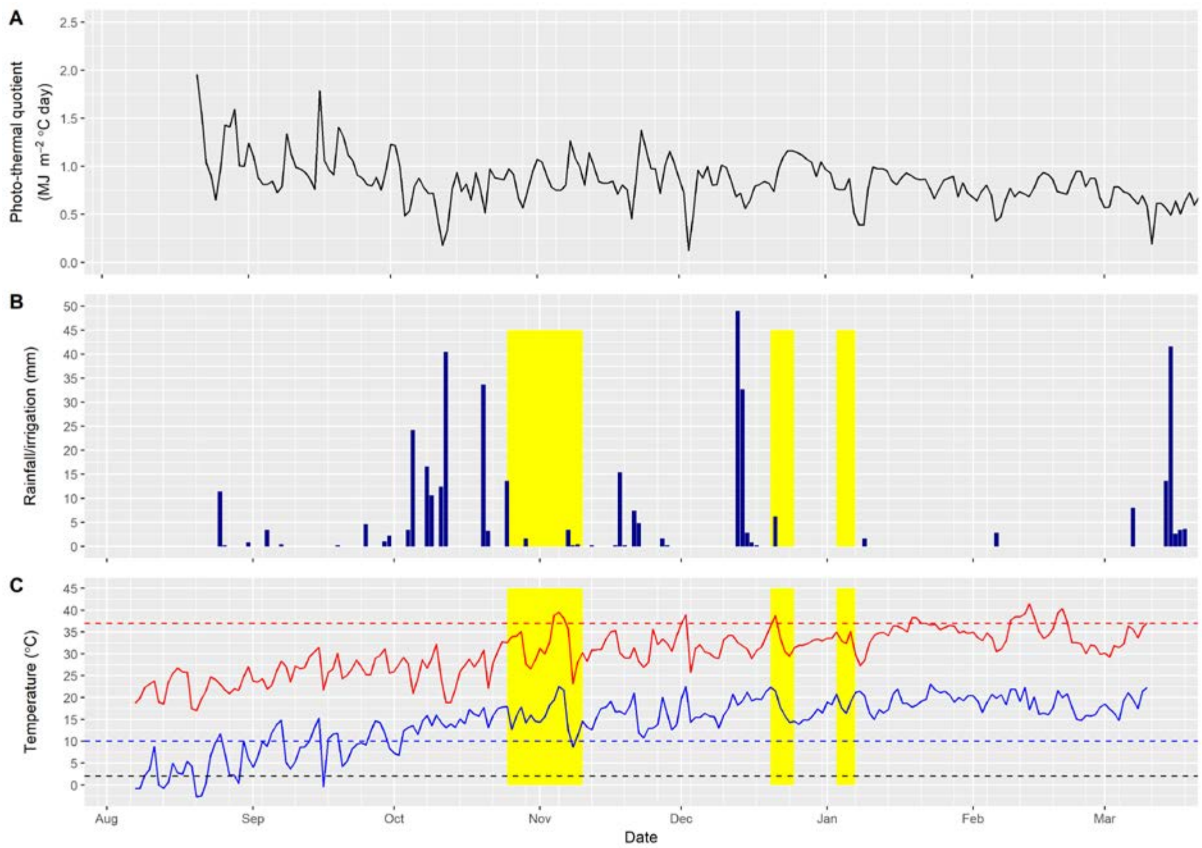

Figure 5. Photothermal quotient (A), rainfall (B) and ambient temperatures (C) at Warra, Qld for the 2018-2019 summer cropping season. The three yellow rectangles indicate flowering timing for each sowing date (see **Table 1**). Solid blue and red lines represent daily maximum and minimum temperatures, respectively. Dashed horizontal represent the reported minimum (blue) and maximum (red) temperatures stress thresholds at flowering and frost (black).

Winter sown sorghum yields

We expect high yields for early sown sorghum crops when water is sufficient, because sunny spring days with cool temperatures (high photo-thermal quotient) should maximise growth rate. However, cool non-freezing "chilling" temperatures can stress some crops and cultivars. Low temperature limits for sorghum growth and development are not characterised for modern Australian hybrids.

At Surat, grain yields averaged across all hybrids were approximately 10 t/ha (11.3 t/ha at 13% moisture content) for all plant populations sown on 8th and 28th of August (i.e. time of sowing 1 & 2; Figure 6). Lack of tillering and water stress contributed to lower yields for time of sowing three (sown 29th Jan 2019) at Surat. The ratooned time of sowing two (28th Aug 2018) crop yielded approximately 75% of the sown time of sowing two crop yield, but similar yield to time of sowing three (24th Jan 2019). The ratoon crop yields were similar to reported yield potential, but time of sowing three that grow during a similar time showed a yield gap. This result will be further analysed in the new GRDC funded project that investigates the impacts of early sowing and ratooning on root growth and water stress.

At Warra, grain yields averaged across all hybrids decreased with latter sowing dates, especially for lowest plant population densities (Fig 6) despite substantially lower pre-flowering rainfall (Figure 5C).

These results mean that sorghum crops can be sown much earlier without yield penalty, supporting 2017-2018 results. Further research on sorghum growth, development and root function at frost and chilling temperatures is required to understand early sown sorghum yield potential.

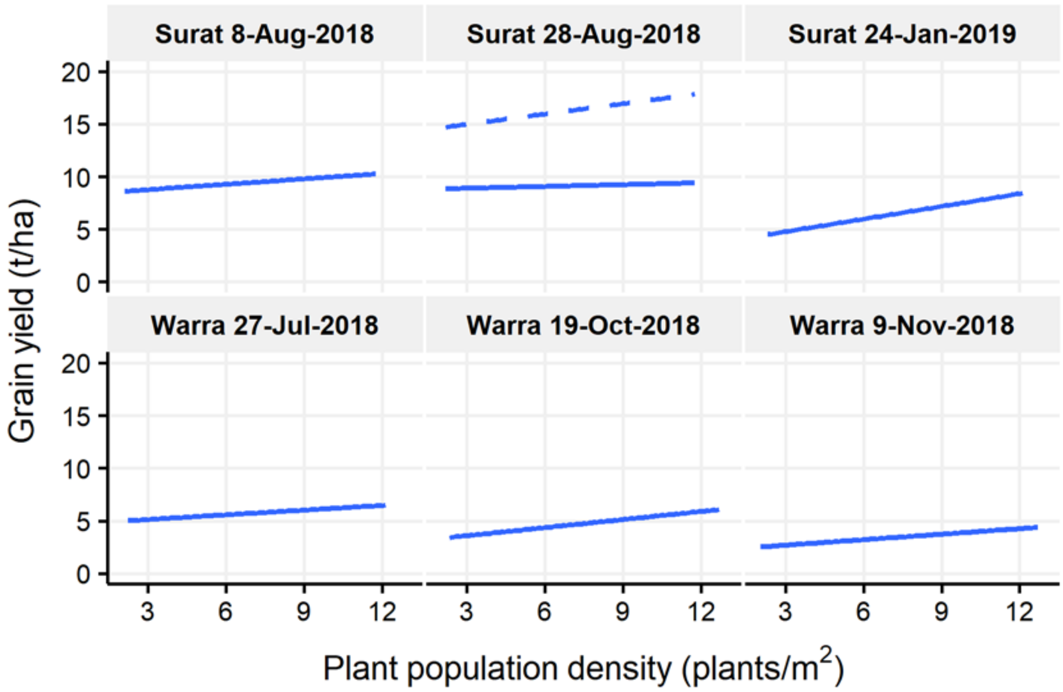

Figure 6. The effect of plant population density on sorghum grain yields averaged across all hybrids for three sowing times at Surat and Warra trial sites for the 2018-2019 summer cropping season. Solid lines indicate grain yield (dry weights) for sown crops and dashed lines show combined sown and ratoon crop yields for the Surat 28-Aug-2018 sowing.

Conclusion

Sorghum can be sown into soil moisture much earlier than recommended, but seedbed temperatures must be monitored in each field and the seed must have high germination rates at low temperatures. Treated stored seed from previous seasons should not be used.

Ratooning of sorghum provides an alternative to cotton, particularly in seasons with low water availability.

The Optimising Sorghum Agronomy project is developing agronomic packages for winter-sown sorghum. For more information follow us on Twitter @Queensland_fsr and at https://www.qld-fsr.info/

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