Winter sown sorghum for Central Queensland

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Key words

Sorghum, establishment, planting windows, seed quality, winter, Central Queensland

GRDC code

UOQ 1808-001RTX

Take home message

- Sowing time for sorghum can be moved earlier than the traditional 16-18 °C soil temperature threshold without significant negative impact on crop establishment and grain yield
- At temperatures of 12°C or greater at sowing depth and good soil moisture at sowing depth, 70% or greater of the target population is usually achieved
- Testing for seed vigour prior to planting is fundamental as seed lot quality, rather than genetics, is the main driver for establishing a sorghum crop into colder soils.

Background

Water stress and extreme heat during flowering can potentially limit sorghum yields across the Northern Grains Region. Traditional sowing windows can expose crops to temperatures in excess of 35°C during the sensitive flowering and grain fill period, resulting in high levels of plant stress, reduced yields, poorer quality grain and in some scenario's, lodging of the crop.

Manipulating sowing dates to avoid these higher stress periods during flowering and grain fill is a logical response. However, there is a long-held belief that crops won't establish in soil temperatures <16°C limiting farmers options to sow earlier to minimise the likelihood of heat and terminal stresses, and their consequences on yield, lodging and screenings.

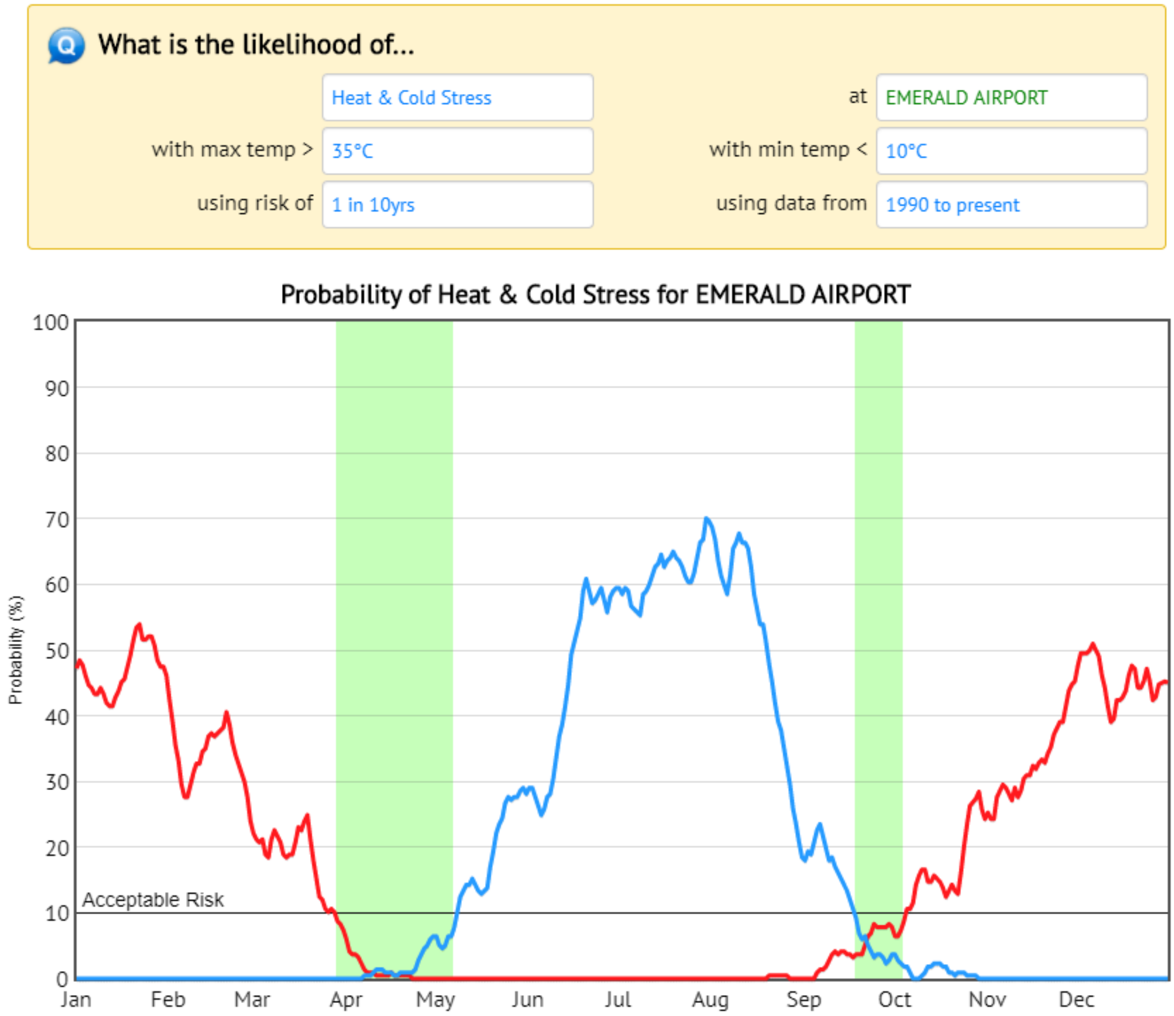
Window shopping

Despite the significant differences between in soil and air temperatures experienced during winter in Central Queensland (CQ) relative to Southern Queensland (SQ) and particularly Northern New South Wales (NNSW), the industry benchmark soil temperature for planting sorghum still limits spring planting dates in CQ to typically a mid to late August planting date. For this reason, spring planted sorghum in CQ is exceptionally rare, and for good reason. July/August/September are traditionally the driest months of the year and receiving sufficient planting rain is rare. In addition, temperatures can spike quickly from late August onwards with the chance of experiencing daily temperature maximums of 35°C increasing to 1 in 3 years by the end of October/early November (Figure 1), which is when an August planted sorghum crop would typically be trying to fill grain in CQ conditions.

Growers in CQ typically plant later in the traditional Dec-Feb planting window for CQ, to avoid extreme heat stress at flowering. However if sowing too late in that window, flowering plants could be exposed to minimum daily temperatures below 10-12°C, increasing the chance of ergot infecting the florets during flowering, particularly in moist or humid conditions (Pažoutová and Frederickson, 2005). An absolute worst case by pushing the flowering date back into late February or March is the grain filling crop getting 'frosted' by a cold blast in late May/June.

Based purely on the air temperature stress risk thresholds; 35°C maximum and 12°C minimum, flowering and grain fill should be taking place in CQ from early April to mid-May for main season crops. For early sown sorghum, a window does exist from mid-September to mid-October (Figure 1) however even the quickest of hybrids in ideal conditions will not be able to hit that window in sub 45 days from planting if sown in mid-August.

Figure 1. CliMate analysis of periods during the year, based on Emerald Airport Data, which would



experience conditions where temperatures would not exceed 35°C or drop below 10°C in 9 out of 10 years.

This project seeks to identify combinations of management (M) and genetics (G) to target optimum flowering windows to minimise the impact of these stresses on grain yield and yield stability. This requires sowing sorghum in winter or early spring, into cooler soils (>12ºC at sowing depth instead of the commonly recommended >16ºC) and managing the canopy size by matching hybrid and population to site and expected seasonal conditions (Rodriguez et al., 2018).

Establishment

While project 'UOQ 1808-001RTX' has several objectives, a primary driver was to test how low (soil temperature) can we go without compromising establishment and how long would establishment take under conditions 4 to 6°C below the recommended "*16°C and rising*" industry threshold (measured at 10cm depth at 8am). Leading on from this was then how long would it take to achieve 50% flowering, and could we hit those 'lower heat stress windows' in Figure 1, simply by planting earlier?

The project is now in its third year. Figure 2 (below) shows the effect soil temperature has had on establishment over the past 3 trials. During 2018/19 and 2019/20 soil temperatures at planting were high and were not a key driver of crop establishment. In 2020/21, this was the only year when the crop was planted into cold soils, and when a response to increasing soil temperature was observed. Crop establishment during 2020/21 varied between 80% at about 12 °C to 100% emergence at 14.5°C.

Establishment does generally improve as soil temperatures increase. The speed of emergence at the August sowing dates was within 10 to 15 days after sowing, where colder June or July sowing dates took up to 20 days plus to reach the same establishment levels. Equally in January 2019, time of sowing (TOS) 3 for the first trial was sown into exceptionally hot and dry conditions. As Figure 2 shows, the average soil temperature at 8am was almost 30°C at seed depth, pushing up toward 40 as a peak during the day, thanks to the bare grey cracking vertosol.

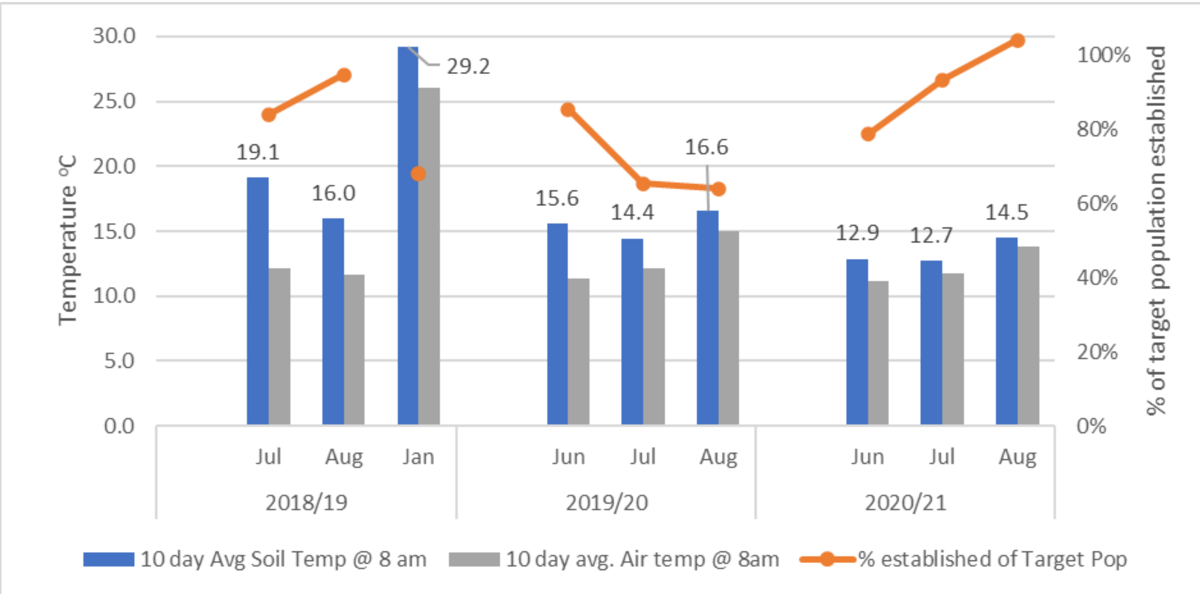


Figure 2. Sorghum establishment conditions for the Emerald trials over the past 3 years. The blue bars indicate 10-day average soil temperature at 8am after sowing, the grey bars indicate average air temperature at 8 am 10 days after sowing and the orange line shows percentage establishment of the target population.

In the 2019/20 trial, establishment was reduced to 65% and 64% for TOS 2 and 3, even though the 10-day average soil temperatures post planting were well above the 12°C ten-day average and plant available water (PAW) at planting was acceptable. This was explained by the fact that TOS 1 seed was from a different seed lot to that of TOS 2 and 3 and while initial seed germination tests were acceptable, the results indicate that vigour was poorer in the seed used at TOS 2 and 3, when compared with that of TOS 1. This has been an important learning from the winter sorghum program, and perhaps the biggest challenge to seed producers.

Hitting windows

The environment from head emergence, through to grain fill can have a significant effect on yield, grain size, test weight and screenings. Based on Figure 1, which relies on historical data, our ideal window (sub 35°C to reduce stress) falls between mid-September and the first week of October for the CQ 'winter sown' trials, while the 'main' season window falls between early April to the second week in May.

Table 1 shows the spread of planting dates used for the CQ trials over the past 3 years. Any flowering dates highlighted in green managed to flower within the target window, based on the CliMate data, while those in black all fell outside the target window.

Table 1. Average days to 50% flowering for all Emerald trials over the past 3 years. Flowering dates coloured green flowered within the CliMate predicted optimum period**.**

Trial Year	Trial	TOS	Sowing Date	Avg. Days to Flowering	Avg. Flowering Date
2018/19	Dryland	TOS 1	26/07/2018	84	**17/10/2018**
		TOS 2	16/08/2018	73	**27/10/2018**
		TOS 3	17/01/2019	53	**11/03/2019**
2019/20	Water Assisted	TOS 1	21/06/2019	115	**14/10/2019**
		TOS 2	22/07/2019	91	**20/10/2019**
		TOS 3	20/08/2019	73	**1/11/2019**
	Dryland	TOS 1	21/06/2019	114	**12/10/2019**
		TOS 2	22/07/2019	92	**22/10/2019**
		TOS 3	20/08/2019	74	**1/11/2019**
2020/21	Water Assisted	TOS 1	23/06/2020	99	**30/09/2020**
		TOS 2	22/07/2020	86	**16/10/2020**
		TOS 3	20/08/2020	65	**23/10/2020**
	Dryland	TOS 1	23/06/2020	99	**30/09/2020**
		TOS 2	22/07/2020	86	**16/10/2020**
		TOS 3	20/08/2020	65	**23/10/2020**

However, widows are only guides, and as Figure 3 shows below, conditions from year to year can vary greatly. The blue bars show average maximum air temperature (°C) 10 days post 50% flowering, while the orange bars show average relative humidity (%) over that same period. The green line with markers shows evapotranspiration (ETo) in mm/day over the 10-day period post 50% flowering.

Preferred conditions post flowering would be sub 35°C maximum average temperatures, relative humidity above 55%, and ETo values below 6mm/day. 2019/20 conditions were exceptionally tough, with the June sowing date flowering in average temps above 35 °C, relative humidity was down to 43% and ETo levels were close to 7mm/day. Conditions did improve slightly for TOS 2 and 3 temperature wise, however relative humidity remained less than ideal and ETo levels were still exceptionally high at 7 mm/day.

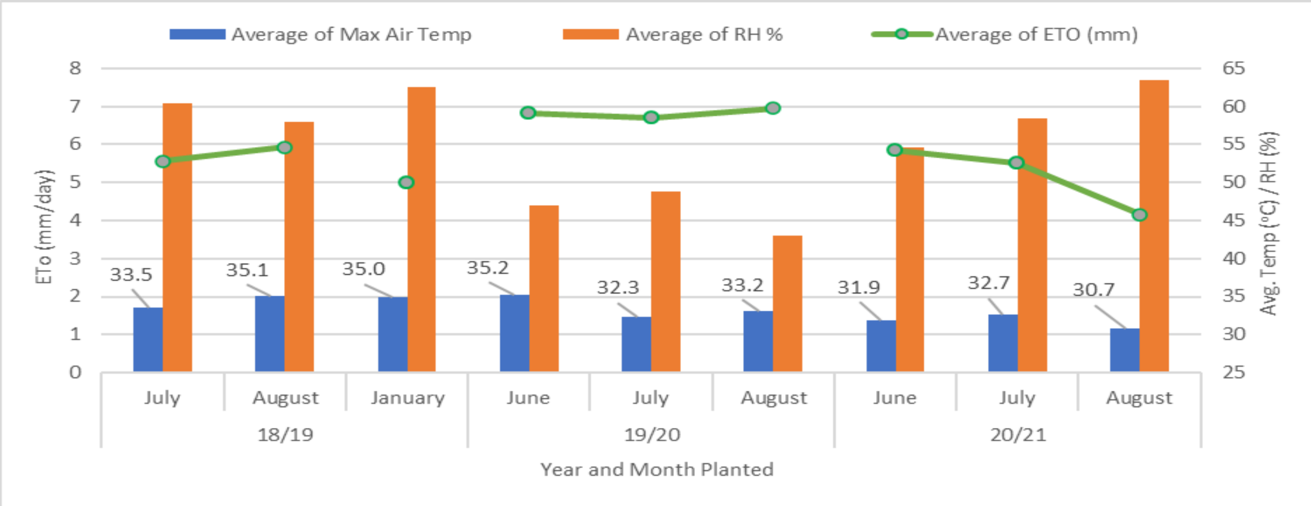


Figure 3. Environment at time of flowering for last three sowing dates. Blue bars indicate average maximum air temperature (°C) for the 10 days post 50 % flowering. Orange bars indicate what the average relative humidity (RH) (%) was for the 10 days post 50% flowering and the green line with markers indicate the average evapotranspiration (ETo) in mm/day.

Project observations

The data collated to date, from not only the CQ trial, but all locations across SQ and NNSW are promising. The project has clearly displayed that a range of commercial hybrids can successfully germinate and establish at levels of 70% or higher of target population in average soil temps as low as 12°C.

While not an ideal scenario, with establishment extending in some conditions to 20 days plus, this expansion of the soil temperature window, potentially opens a new planting window for CQ regions and also improves options for SQ and NNSW. Further to this we have seen seedlings withstand frosts both in CQ and the southern sites as advanced as 6 leaf (Figure 4).

Figure 4. "Frosted" TOS 1 plants on the 13 of August 2019 in Emerald. No plants were lost due to these events. Typically if the primary stem were lost, additional tillers would take its place.

Plant development tends to change with winter sown sorghum. The two most obvious changes are that winter sown sorghum tends to be significantly shorter (10 to 15cm on average) and in the cooler conditions will tiller far more prolifically, even in higher target populations, compared to a main season crop at the same target population. (Figure 5)

Once established, the winter sown sorghum, if planted into good moisture, seems more resilient to dry conditions prior to head emergence, when compared to a main season planted crop.

Figure 5. June 2020 planted Cracka sorghum in a low population plot on the 18th September with 8 tillers. Higher than average tiller counts in populations as high as 90000 plants/ha are often observed.

It is still preferable to receive in crop rainfall, preferably at or around the flowering/head emergence period, as supported by the 2019 data set. Both the 2020 and 2018 trials received storm rain of more than 50 mm over a week close to or at grain fill, which significantly assisted during the grain fill period. The 2019 crop did not receive any significant rainfall, particularly around flowering and grain fill (Figure 6), as such the 2019 dryland trials struggled to achieve a yield of more than 1 t/ha, where the 2018 trial yielded more than 4 t/ha.

Figure 7, based on data from the 2018 trials across QLD and NNSW, shows a relationship between post flowering temperatures and grain yield. There was a significant interaction effect between post-flowering maximum temperature and plant population, but not between post-flowering maximum temperature and hybrid. Based on the 2018 data set, the model predicts that yields will be maximised at temperatures below 33^{o}C, but also with a higher established population. It must be noted that this prediction does not account for other environmental effects, including limited water.

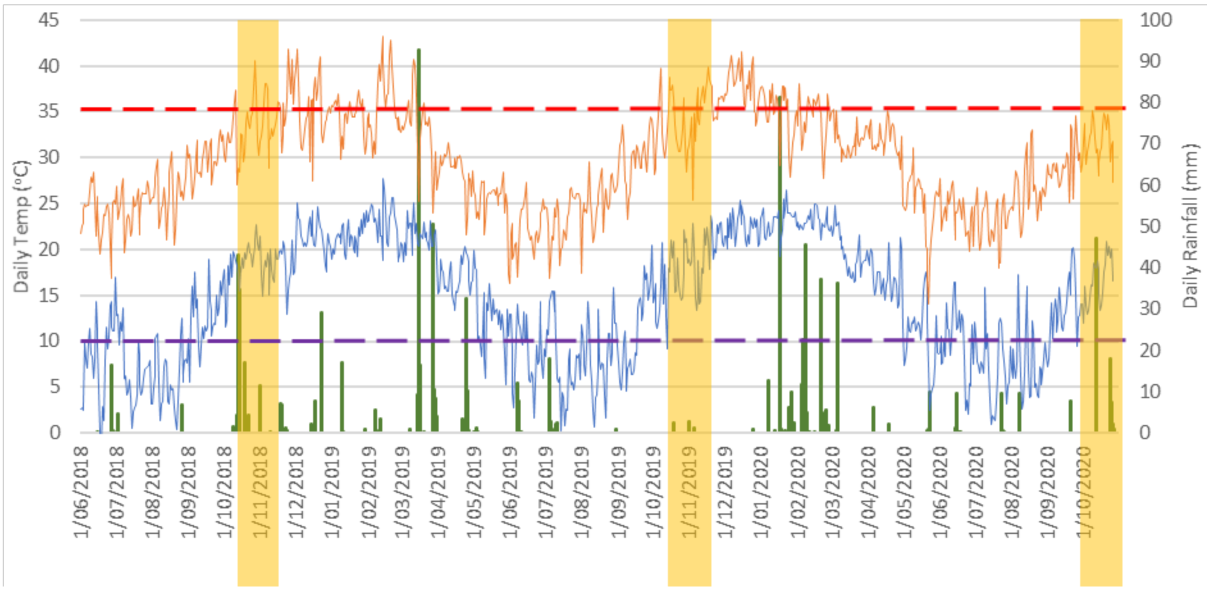


Figure 6. Daily air temperature range and rainfall over the duration of the project to date. Graph shows daily minimum (blue), maximum (orange) temperatures and daily rainfalls (green bars). The red dotted line indicates where heat stress will be experienced, the purple line indicates when the chance of ergot may increase. The yellow bars represent the 3 flowering periods for 2018, 2019 and 2020 trials.

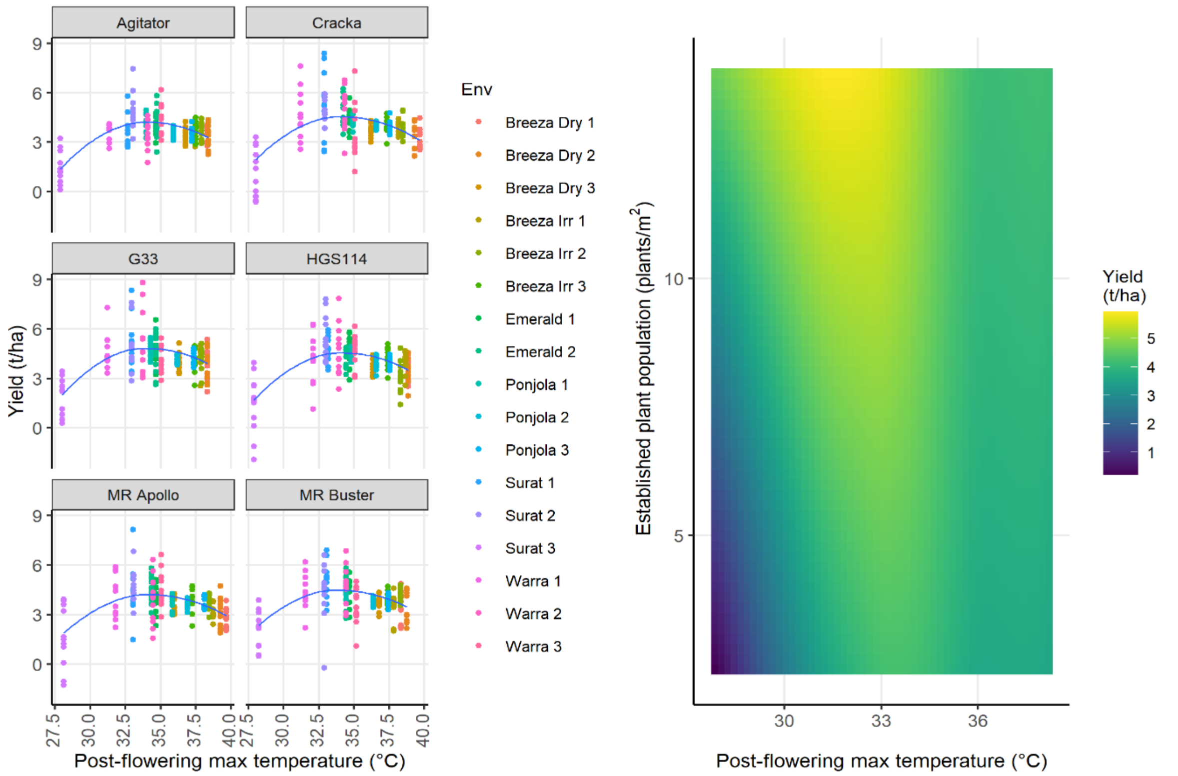


Figure 7. Grain yield predictions (E-BLUEs) of post-flowering maximum temperature (°C) with respect to i) hybrid and ii) established plant population. There was a significant interaction effect between post-flowering maximum temperature and plant population, but not between post-flowering maximum temperature and hybrid. The points denote plot grain yield adjusted for all other environmental covariates and unaccounted environment effects.

Call to action

To date, the Winter Sorghum project has been systematically kicking goals across a range of environments in the Northern Grains region. The project now has three years of data supporting the resilience and tolerance of germinating sorghum to what were considered unthinkable starting soil temperatures for the crop. And while 12^{o}C would not be a suggested sowing temperature, we now know that acceptable establishment can be achieved at these temperatures, should a cold change come through post sowing. We also know the young seedlings are far more tolerant to a frost event, down as low as -2 ^{o}C across multiple sites, with minimal mortalities.

The project has also established the Achilles heel of a winter sorghum, that being seed quality, and more importantly, seed vigour. Germination tests alone are not guarantee that vigour will be acceptable, particularly in the coolest of conditions. Sourcing fresh, high vigour seed will present a major challenge to all seed companies if this practice is to become more widespread.

From a CQ point of view, winter sorghum is not a simple decision. While it certainly reduces the chance of heat stress conditions at flowering, relative to an August or early September planted crop. The significant ETo (evaporation) pressure and heat typically experienced during grain fill, almost demands some kind of rainfall during the flag leaf to grain fill period to maximise yields, even with a full planting profile at sowing

If considering trying winter sown sorghum in CQ, we would suggest the following interim points based on observations to date:

- Plant on a full profile of moisture and ensure there are no nutritional limitations to limit root development or water uptake
- Plant into soil with good ground cover/standing stubble, to reduce evaporation losses and temperature fluctuations and protect young seedlings
- Increase your target population. If you normally target 40,000 plants/ha for a main season planting, target 50 to 60,000 plants/ha to allow for a reduction in established plants
- Aim to have flowering/grain fill well advanced before temperatures exceed 35^{o}C
- Try and jag a storm or two at flowering to maximise yields! 😊

References

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Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

This project is led by Dr Daniel Rodriguez (d.rodriguez@uq.edu.au) from The University of Queensland (UQ) and run in collaboration with Loretta Serafin (NSW DPI), Jane Auer, Ian Broad & Ellie McCosker(QDAF), Joe Eyre, Erin Wilkus and Peter deVoil (UQ), Michael Mumford and Alison Kelly (SAGI-QDAF)

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