Optimising sorghum grain yield in western growing regions – a focus on agronomy and nutrition

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PROC -9176856 – Increasing sorghum area in northwest NSW through understanding and adoption of early sown sorghum principles.
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Take home messages

- Ensuring starting soil water >150 mm and a low weed seed bank is essential for improving the likely success of sorghum crops in western regions of northern NSW
- August planting once soil temperatures are at 13 °C and rising provides an opportunity for early sowing, with a very low risk of frost damage after 7 leaves or floral initiation
- Establish 5–6 plants/m^2, regardless of the row configuration; this population has been the most reliable performer across sites and seasons, west of Moree
- In high yielding seasons solid plant rows (50–100 cm) will outperform single and double skip.
- In lower yielding seasons (<4 t/ha), more data is required to establish the performance of narrow (50 cm) row spacings
- Positive grain yield responses to nitrogen have been demonstrated in the last two seasons. The economics of applying nitrogen to sorghum in western regions will depend on seasonal pricing of sorghum grain and nitrogen, and the predicted grain yield.
- Across two years of testing, a soil N bank target of ~170 kg N/ha provided the best economic returns from vary contrasting starting soil N levels.
- Low grain protein <9% is often a useful indicator of significant nitrogen deficiency.

Introduction
Western growing regions of Northern NSW have long been recognised for their ability to reliably produce winter crops, but they also have the potential to produce significant areas and tonnages of sorghum.

Research over the last 15 years has led to changes in our agronomy practices and identification of ways to optimise crop performance in the region. Advances in our knowledge into the future will continue to push the yield frontier further.

Maximising crop performance always starts with good rotational practices, such as maintaining clean fallows and ensuring soil water profiles are full prior to planting. In western regions research indicates profit and risk management are best considered with >150 mm of starting PAW. This paper contains an overview of the current knowledge for optimising crop yield potential for sorghum in the west.

Small steps to achieve big changes in the western regions
Over the last fifteen years, we have conducted research in northwest NSW to develop our knowledge of the best methods to optimise sorghum production in this variable environment.

This research has covered row spacing, plant population, hybrid selection, time of sowing and nitrogen nutrition. The results of these trials have each provided yield gains which have led to a focus on delivering a combined package for sorghum agronomy in this environment.

How many plants do I need to maximise grain yield?

Grain yield responses to plant population has been tested across a wide range from very low (~1.5 plants/m^2) to very high (~12 plants/m^2). These populations have been tested across the main row configurations used in the region; 100 cm solid, single skip, double skip and super wide rows (150 cm solid) (Figure 1).

Plant population is a balance between establishing enough plants to achieve the maximum potential yield and to avoid any unnecessary expenditure on seed costs. Plant population is firstly about maximising grain yield but also has implications for weed competition, improving resource capture and efficiency (water, sunlight etc) and crop evenness for pest control and desiccation.

In areas west of Moree - as a rule of thumb, establish 5–6 plants/m^2, regardless of the row configuration; this population has been the most reliable performer across sites and seasons. Establishing higher populations (we have tested at 9 and 12 plants/m^2) has not provided any grain yield benefits. In contrast, establishing less than 3 plants/m^2 has limited yield potential. Very low plant populations also deliver additional challenges with gaps and uneven plant stands in a paddock.

Which row spacing to use?

Sorghum can be successfully established and grown on row spacings as close as 25 cm or as wide as a double skip on 100 cm configurations. The choice of row spacing depends on your attitude to risk in your growing environment, starting soil water, seasonal forecast, availability of machinery and system fit.

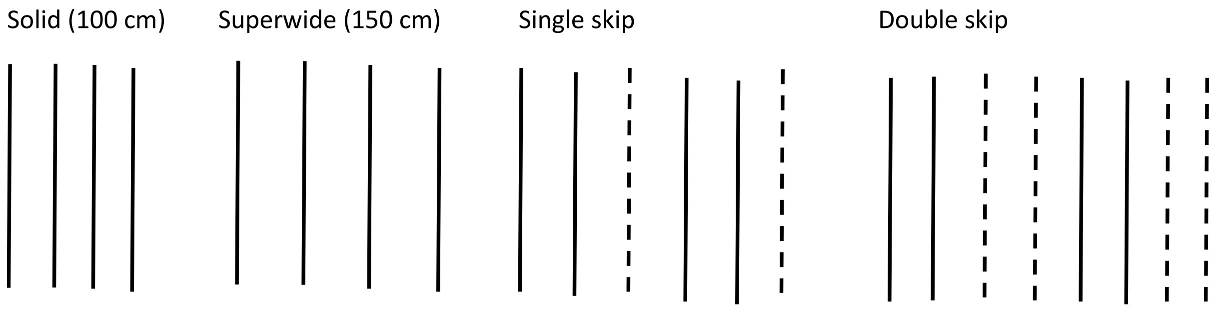

Figure 1. Row configurations used in sorghum.

The recommended row configuration where yield expectations are >3.5 t/ha has been 75–100 cm using a precision planter. The use of precision planters enables less seed to be used, more uniform seed spacing and a more even crop maturity. However, sorghum can still be established using air seeders, although the risk of poorer establishment outcomes is higher.

Sorghum has a strong compensatory mechanism through its production of tillers and will respond to competition and environmental conditions. It is recommended to match your row spacing to your expected yield and the available soil water. As a rule of thumb, >3.5 t/ha use solid plant row spacing's and for <3 t/ha use 100 cm solid or consider skip or wide row configurations.

Recently there has been increased interest in the use of narrow row sorghum in the western regions (50 cm or less). The interest in narrow row spacings relates to the ability to utilise existing winter planters for summer crop planting and hopes of increased ground cover and improved fallow infiltration and retention under closer plant rows.

Research results from the last two seasons which include narrow row sorghum are preliminary in nature, as they are from sites where yields were >4.0 t/ha. In the 2021/22 season, with a site average yield of 8.2 t/ha at Mungindi, there was no significant difference between 33, 50 and 100 cm row spacings. In the 2023/24 season at Weemelah with a site mean yield of 6.1 t/ha there was no difference between 50 and 100 cm solid row spacings, however there was a decline in yield from using single skip (Figure 2).

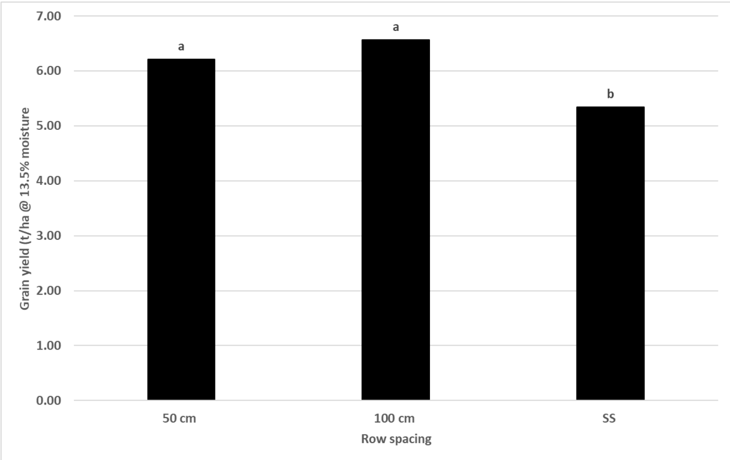

Figure 2. Grain yield at three row spacings at Weemelah, 2023/24. Data with the same letter are not significantly different (*P*<0.05).

At Millie, where average yield was 4.31 t/ha, there was an interaction between hybrid type and row spacing. At this site there was no significant difference between the yields at 50 and 100 cm row spacings for A14 and Viper IG but Halifax yielded significantly less than the other 2 hybrids at the 50 cm spacing only. Single skip yields were lower for the quick maturity hybrid Viper IG (Figure 3).

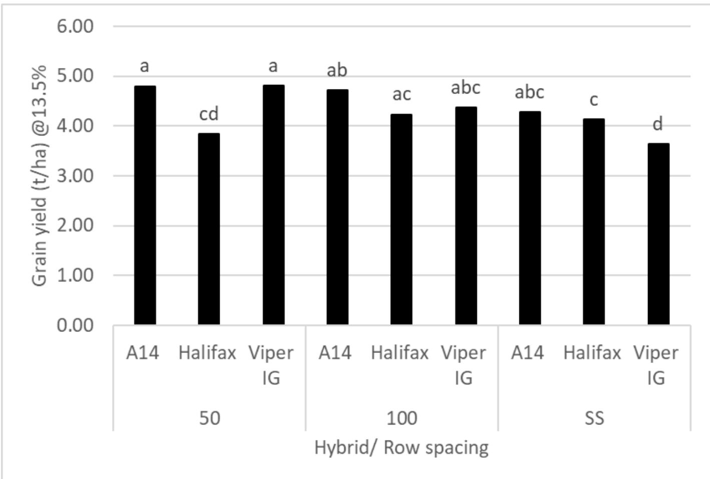

Figure 3. Grain yield at three row spacings and hybrids at Millie, 2023/24. Data with the same letter are not significantly different (*P*<0.05).

Therefore, based on the available data there has been no difference between 50 and 100 cm rows spacings, except for Halifax this season with yields greater than 4.0 t/ha. It may be premature to use these results for yields <4.0t/ha. The next season will hopefully provide data on the response of narrow versus 100 cm rows in lower yield scenarios of 2 – 4 t/ha.

The advantage of wide or skip row spacing is the ability to conserve water in skip areas for flowering and grain fill as the plant roots are generally unable to explore this area fully before flowering. Weed control is more critical in wide row configurations because of the lower interrow competition. If weeds are not controlled adequately the advantage of a wider row configuration maybe negated. These wider row spacings are very reliable but also cap yield outcomes in high yielding seasons.

When is the best time to plant?

The ideal time to plant sorghum is always a compromise. Planting is encouraged when you can meet the highest number of "ideal" parameters for successful establishment and yield. Sowing time is recommended to be either early (August) or late (December/January) in the western growing regions, depending on your attitude to risk and fit with your other farm operations. These timings ensure the critical flowering period received the likely best temperature conditions and avoids yield loss due to heat stress. Early sowings may also allow plant establishment before FAW can increase its population.

It is not recommended to plant during October and November in most situations as the crop will reach flowering and grain fill in December/January when the risk of heat stress is high. This can reduce head exertion, seed set, crop yield and increase the likelihood of crop failure.

Regardless of the planting time, the soil moisture profile should be full (>150 mm) and seedbed moisture should be sufficient to support the germination and emergence process, which can be 14 days for early sown sorghum and 7 days for late sown sorghum.

Table 1. Pro's and con's of early or late planting times

Early planting (August)		Late planting (December/ January)	
Pro's	**Con's**	**Pro's**	**Con's**
Crop should flower before the extreme heat period. Crop establishment in a period of low FAW pressure.	Soil temperature needs to reach a minimum of 13°C and rising. False starts can reduce establishment.	Fallow weed control can be completed to ensure weeds are controlled.	Soil temperature can be very high, reducing seed emergence and drying out the seedbed quickly.
Crop yields will be as good or better than planting in September.	Crop growth and development will be slower, so it takes more days to reach 50% flower.	Seed will rapidly emerge due to very warm soil temperature.	Later to flower, slower maturity and grain dry down. Harvest will be late so grain may need to be dried. Shorter days mean fewer harvest hours.
Earlier harvest, usually from mid-January. This starts the fallow re-fill earlier, allowing the possibility of double cropping.	Paddocks need to be clean of winter weeds, e.g., black oats, as the crop will be emerging when these species can still be germinating.	Opportunity to wait longer for a full soil moisture profile prior to planting.	Harvest can clash with winter planting.
Avoid clashes with winter crop planting & harvest.	High quality seed is needed. Hybrid cold tolerance varies so hybrid choice is important.	Crop growth and development will be quicker. Most hybrids will flower in 65–70 days.	There is no opportunity to double crop, so a long fallow is required to move back into a winter crop.

Nutrition

The attitude towards crop nutrition in the western regions is steadily changing, as agronomy practices have improved crop reliability and overall yields. Data from the Australian Bureau of

Statistics on sorghum production in NSW shows that in the 10-year period between 2005-6 and 2015-16 average yields have increased by more than 1.0 t/ha, from 2.72 t/ha in to 3.80 t/ha.

As such, it seems reasonable that we should be investing in crop nutrition in line with increasing yield if it is supported by positive economic returns. It is still more common for dryland sorghum in this environment to be planted without the application of any nitrogen and in some cases without any starter fertiliser. Historically we invested in fertilising our wheat and relied on following sorghum crops to utilise the remnant nitrogen after the wheat, as well as mineralised nitrogen which became available during the long fallow.

Nitrogen

Nitrogen remains the crop nutrient required in the largest amounts for crop production. In grain sorghum we remove ~15 kg of nitrogen (N) for every tonne of grain so on average we are exporting ~60 kg/ha in every 4-tonne sorghum crop. In may crops the industry standard is to assume the N removed in grain is doubled to estimate the N required in the soil meaning ~30 kg of soil N is required for every tonne of sorghum grain or 65 kg of urea/t. Estimates of soil mineralised N are essential for sound budgeting and are subtracted from the projected crop N requirements to determine fertiliser N inputs. Potential yield is reached with grain protein levels above 10%, between 9 and 10% N is considered to be marginal and below 9 % N is deficient.

In 2022/23 and 2023/24 experiments were conducted at Millie testing nitrogen application timing and rate. Eight nitrogen treatments were applied in the form of urea, including a nil treatment and a mix of upfront, in crop (6 or 10 leaf growth stage) or split applications.

In 2022/23 the site started with 81 kg/ha nitrogen in the top 120 cm. The average site yield was 3.4 t/ha and total soil N requirement based on this yield at 50% efficiency was 102 kg/ha. Subtracting the soil N of 81 kg/ha indicates at least 21 kg of fertiliser N/ha was required or ~46 kg urea. There was a positive grain yield response of more than 1.0 t/ha to any additional urea applied (Figure 4a).

The highest yield (Upfront 210 kg/ha urea Figure 4a) advantage was 1.2 t/ha priced at $320/t is a $384/ha advantage. The cost (N cost) of achieving this yield in this experiment was $147 assuming a urea cost of $700/t. Applying a spreading cost of $15/ha and based on the price assumptions, the partial gross margin benefit was $222/ha. The lowest yielding N treatment (figure 4a) was upfront 140 kg urea with a yield advantage of 0.7 t/ha and a partial gross margin of $111/ha.

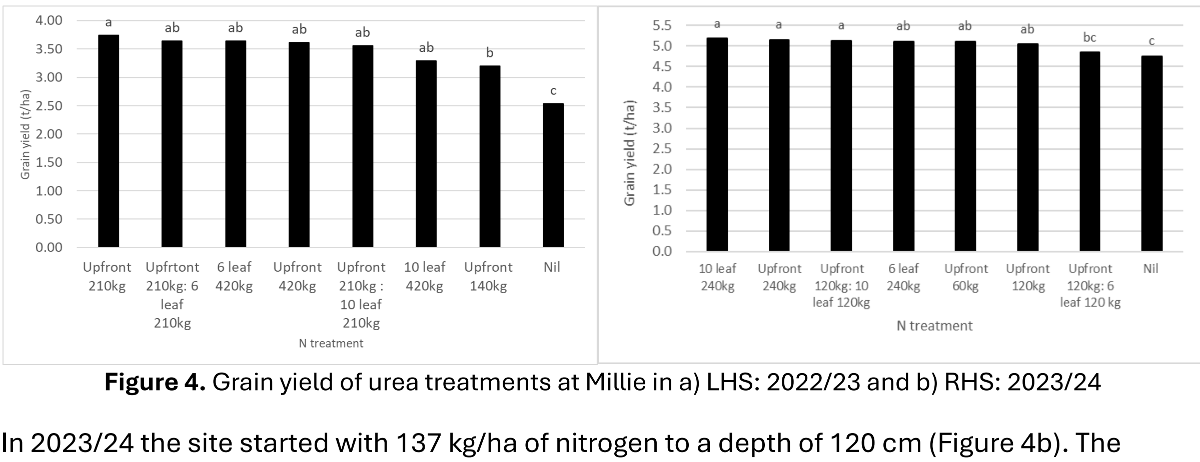

Figure 4. Grain yield of urea treatments at Millie in a) LHS: 2022/23 and b) RHS: 2023/24

In 2023/24 the site started with 137 kg/ha of nitrogen to a depth of 120 cm (Figure 4b). The average site yield was 5.04 t/ha. There was an increase in grain yield of ~0.3–0.4 t/ha from the application of any urea over the nil treatment (Figure 4b). Comparing the Upfront urea at rates

240 and 60 kg urea/ha they both achieved a yield increase of 0.4 t/ha and partial gross margins of -$58 and $68/ha respectively.

In this work the 2022/23 season where starting N was 81 kg/ha and added N upfront was ~97 kg N/ha (210 kg urea/ha) it provided a soil bank of ~178 kg N/ha while in 2023/24 the starting N was 137 kg N/ha and upfront N was ~28 kg N/ha (60 urea /ha) it provided a soil bank of ~164 kg N/ha. In these circumstances a total N bank of between 160 and 180 kg N/ha provided a partial gross margin between $111 and $222 per ha with the lower return associated with high starting soil N. While the sites varied greatly in starting N, topping the N bank up to ~170 kg N/ha was most profitable across both seasons. A positive response was also recorded in grain protein, with more than a 1% protein increase from 8.36% to 9.99% from applying 240 kg of urea (data not shown).

It is important to remember that yield responses to nitrogen application will vary between seasons and the decision to apply nitrogen should be based on measurement of the starting soil nitrogen level, the price of the nitrogen fertiliser, starting soil water, potential crop yield and likely economic return. However, results from the last two seasons support that additional nitrogen to a N bank target of ~170 kg N/ha can result in higher yield and profit in this region.

Conclusions

The research and agronomic advancements over the past fifteen years in north western NSW have significantly improved our understanding of sorghum production, leading to optimized practices tailored for this variable environment. Key areas of focus such as row spacing, plant population, hybrid selection, time of sowing, and nitrogen nutrition have collectively contributed to yield gains.

Timing of planting is crucial, with early (August) and late (December/January) sowing recommended to avoid heat stress during critical growth periods. Adequate soil moisture (>150 mm) is essential for successful and early sowings (rising temperature plain from 13°C has the additional advantage of avoiding FAW in the early establishment phase.

Establishing optimal plant populations, specifically 5-6 plants/m^2, has been shown to reliably maximize grain yield across different row configurations. Row spacing decisions should be guided by yield expectations and soil water availability, with solid plant rows recommended for yields above 4.0 t/ha and skip or wide rows for yields below this threshold.

Nitrogen removal in sorghum grain is ~15 kg N/t. Recent trials indicate that maintaining a total nitrogen bank of 160-180 kg N/ha can enhance both yield and profitability. It's essential to base nitrogen application decisions on current soil water and nitrogen levels, and economic considerations.

Continued research management strategies and genetic adaptation will further enhance the region's capability to produce high-yielding sorghum crops, contributing to the sustainability and profitability of local farming systems.

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