High competition sorghum – impacts on crop productivity, water and nutrient use legacies in the farming system

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Take home message

- Narrow row spacing and higher plant populations in sorghum crops can offer potential for higher weed competition, with higher early crop biomass and early ground cover
- While crop biomass and yield potential can be increased with high-competition sorghum crops, this can increase yield in better seasons but increase risks of yield penalties in drier conditions
- Higher density sorghum crops often extract more soil mineral N and may immobilise some mineral N during the subsequent fallow – a function to growing more biomass
- High competition crops did not extract more soil water and the extra, and more even, crop residue was not sufficient to enhance fallow efficiency
- High-competition sorghum crops will require more starting soil water and available N to meet the demands of growing more biomass.

Introduction

Grain sorghum is often grown on wide row spacings (1m or more) with moderate to low plant populations (<60 K plants/ha) to help manage water use through the season and maintain yield stability under dry conditions. While this can have benefits in some seasons, this presents challenges for weed control, particularly grasses, due to low competition from the crop meaning that the limited suite of residual herbicides are critical. However, there are very limited options for pre-emergent control of grass weeds in grain sorghum and these herbicides can sometimes limit future crop choices, place pressure on limited herbicide options for the development of resistance, and in some circumstances, allow sufficient weed escapes to enable weed seedbank replenishment, or at worst a weed seed blowout. Wide rows can also leave low and unevenly distributed crop residues with implications for fallow water accumulation, resulting in uneven sowing moisture for subsequent crop establishment.

In our farming systems research, we are implementing an 'Integrated Weed Management' system which aims to compliment herbicides by increasing in-crop competition for weeds through growing crops on narrower row spacings at higher densities. In our experiments, we are not testing the capacity of the high competition crops to suppress weeds (we are maintaining a system with low weed populations) but this allows us to compare the impacts of this practice on diverse aspects of the farming system (e.g. soil water and nitrogen extraction and accumulation, subsequent crop performance) compared with conventional practice. In this paper we report on 5 seasonal comparisons where sorghum crops were grown to produce high competition via narrow rows (0.5 m compared with 1 m) and higher seeding densities (25-70% higher) compared to conventional practice. These involved crops grown in 2017/18 at our farming systems sites in Emerald (Central Qld), and Pampas (Eastern Darling Downs) and three subsequent crop comparisons at Pampas in 2018/19, and 2020/21.

Crop performance

Tables 1 to 4 show each of the seasonal comparisons of the high-competition and conventional sorghum crops in terms of the crop densities and seasonal conditions, crop performance, i.e. grain yield, biomass, water-use-efficiencies, soil water and nitrogen extraction and legacy impacts on subsequent fallow water and nitrogen accumulation (this data isn’t available for 2020/21 crops as yet). In all cases crops were sown with very similar or equivalent plant-available soil water (PAW) at the opening of the sowing window and in all cases PAW had exceeded 150 mm prior to sowing.

Crop yield and biomass

Across the 5 seasonal comparisons we have seen yields of the high-density sorghum crops range from an 18% increase (Emerald 17/18) to a 45% decrease (Pampas 2020/21). The high-competition crops have resulted in a higher yield in one of the 5 seasons (Table 1), two seasons produced the same grain yields (Tables 2 & 3) and a yield penalty occurred in the final comparisons in the same year (Table 4). These results occurred for seasons that produced crop yields in our conventional crops ranging from 3.4 t/ha to 5.4 t/ha.

While grain yields have not been significantly increased, the biomass of crops have increased by 10-30% in 4 of 5 seasons. This is a result of the higher plant populations allowing earlier growth and resource capture. However, despite the higher biomass this did not translate into higher yields, meaning that these crops have resulted in lower harvest index (i.e. ratio of grain to biomass). This often indicates that high competition crops may have encountered more moisture stress during grain filling which reduced their capacity to fill grain and realise higher yield potentials. We would expect this to occur more in seasons with lower grain yields. Our data does support this, with a significant yield penalty occurring in the high competition crops at Pampas in 2020/21 which had the lowest yields, despite the high in-crop rainfall (much of which occurred very late in the season).

Table 1. Performance and legacy impacts of high competition sorghum crops compared to conventional practice at Emerald in 2017/18. Cultivar MR Buster sown on 22 Jan 2018.

CROP CONDITIONS	**High comp.**	**Conven.**	**Difference**
Row spacing (m)	0.5	1.0	
Target density ('000 plants/ha)	60	40	
Pre-sow plant-available soil water (mm)	145	145	-
In-crop rainfall (mm)	224		
CROP PERFORMANCE			
Grain yield (t/ha)	5.9	5.0	+0.9
Crop biomass (t/ha)	15.6	11.6	+4.0
Grain WUE (kg grain DW/mm)	18.9	16.0	+3.0
Biomass WUE (kg DM/mm)	48.6	36.5	+12.1
Soil water extraction (mm)	97	97	-
Change in soil mineral N (kg/ha in 0-90 cm)	-100	-110	-10
LEGACY IMPACTS (11-month fallow, 417 mm rain)			
Fallow soil water accumulation (mm)	72	96	-24
Mineral N accumulation (kg/ha)	75	89	-14

Water, N use and WUE

We have not measured any large differences in terms of final soil water extraction between the high competition and conventional crops, meaning that both crops have ultimately used a similar amount of water from the system. However, the timing of this water use may have differed (as mentioned above). This means that the grain WUE and biomass WUE of the crops closely reflect the relative grain yields and biomass achieved. The higher biomass WUE observed in all crops indicates that the higher densities are transpiring a larger proportion of the available water, and less is lost to evaporation. However, as discussed above, this has not always translated into a higher grain yield.

In all these comparisons all crops had very similar starting levels of soil mineral nitrogen and received the same fertiliser applications. However, the data does show that on average the high-competition crops have y extracted more soil mineral N than the conventional crops by about 20 kg N/ha. This extra N use is associated with the greater biomass growth.

Table 2. Performance and legacy impacts of high competition sorghum crops compared to conventional practice at Pampas in 2017/18. Cultivar Taurus sown on 3 Nov 2017

CROP CONDITIONS	**High comp.**	**Conven.**	**Difference**
Row spacing (m)	0.5	1.0	
Sowing rate (kg/ha)	4.7	3.5	
Established density ('000 plants/ha)	90	68	
Pre-sow plant-available soil water (mm)	125	160	
In-crop rainfall (mm)	195		
CROP PERFORMANCE			
Grain yield (t/ha)	5.4	5.4	-
Crop biomass (t/ha)	16.0	14.1	+1.9
Screenings (%)	0.2	0.1	-
Grain WUE (kg grain DW/mm)	11.3	11.2	+1.0
Biomass WUE (kg DM/mm)	33.8	29.3	+4.5
Soil water extraction (mm)	105	110	-
Change in soil mineral N (kg/ha in 0-90 cm)	-130	-107	+23
LEGACY IMPACTS (20-month fallow, 559 mm rain)			
Fallow soil water accumulation (mm)	96	63	-33
Mineral N accumulation (kg/ha)	113	126	-13

Table 3. Performance and legacy impacts of high competition sorghum crops compared to conventional practice Pampas 2018/19. Cultivar Taurus sown on 26 Oct 2018.

CROP CONDITIONS	**High comp.**	**Conven.**	**Difference**
Row spacing (m)	0.5	1.0	
Sowing rate (kg/ha)	3.7	3.0	
Established density ('000 plants/ha)	85	66	
Pre-sow plant-available soil water (mm)	130	130	
In-crop rainfall (mm)	153		
CROP PERFORMANCE			
Grain yield (t/ha)	4.4	4.5	-0.3
Crop biomass (t/ha)	10.1	9.1	+1.0
Screenings (%)	0.3	0.3	-
Grain WUE (kg grain/mm)	11.5	11.3	-
Biomass WUE (kg DM/mm)	25.7	23.0	+2.7
Soil water extraction (mm)	116	117	-
Change in soil mineral N (kg/ha in 0-90 cm)	-39	-20	+19
LEGACY IMPACTS (17-month fallow, 440 mm rain)			
Fallow soil water accumulation (mm)	119	133	-14
Mineral N accumulation (kg/ha)	79	85	-6

Legacy impacts

We had expected that the higher crop biomass achieved by the high-competition crops could result in higher levels of residue ground cover and potentially enhance the accumulation of soil water in the subsequent fallow. However, our results do not support this. Following all 3 crop comparisons we have followed so far, we have seen very little difference in soil water accumulation over long fallows (11-20 months) following the high-competition crops, and no clear benefit for subsequent fallow efficiency. Two sites saw slightly lower fallow water accumulation within measurement error (Tables 1 & 3), while the other comparison the higher density crop accumulated 33 mm more soil water over a long fallow (Table 2). It could be that the differences in crop biomass (about 10% extra) are not sufficient to dramatically influence ground cover and hence rainfall infiltration enough. Further, most of these crops will have left 6-10 t DM/ha of residue after harvest and ground cover of >50% meaning that the benefits of additional biomass are likely to be low. Under conditions with lower ground cover and/or wetter fallow periods, perhaps differences might be more evident and favourable following the high-competition crops.

Despite the higher biomass and N uptake by the high-competition crops, this additional N did not mineralise during the subsequent fallow and result in higher N accumulation following the high-competition crops. In fact, the high-competition crops often results in slightly lower N accumulation during the subsequent fallow (6-15 kg N/ha). These differences could be the result of the higher amounts of residue biomass, with sorghum stubble often having a high C:N ratio this can immobilise more mineral N from the soil. These differences are small and not likely to influence subsequent management.

Table 4. Performance of high competition sorghum crops compared to conventional practice at Pampas 2020/21. These crops had different cropping histories, either following a long-fallow (left) or a short fallow (right). Cultivar Taurus sown on 5 Nov 2020.

	Sown following long fallow			Sown following short fallow		
CROP CONDITIONS	**High comp.**	**Conv.**	**Diff.**	**High comp.**	**Conv**	**Diff.**
Row spacing (m)	0.5	1.0		0.5	1.0	
Sowing rate (kg/ha)	5.0	3.2		5.0	3.2	
Est. density ('000 plants/ha)	91	53		86	53	
Pre-sow PAW (mm)	135	145		100	105	
In-crop rainfall (mm)	377			377		
CROP PERFORMANCE						
Grain yield (t/ha)	2.1	4.1	-2.0	2.7	3.4	-0.7
Crop biomass (t/ha)	8.6	9.3	-0.7	7.5	7.1	+0.4
Screenings (%)	6.5	5.1	+1.4	4.0	4.0	-
Soil water extraction (mm)				+20	+15	-
Grain WUE (kg grain/mm)				7.6	9.4	-1.8
Biomass WUE (kg DM/mm)				21.0	19.6	+1.4

Concluding remarks

We have found mixed results from growing sorghum to induce higher crop competition, with upsides for yields in some seasons and clearly some downsides in others. It does seem that the potential downside risks increase from around 60 K plants/ha to higher populations (For example over 90 K plants/ha) while a benefit was seen when populations increased from 40 to 60 K plants. Hence, there could be a case for increasing plant populations from low levels or with very wide row spacings. However, further understandings of the limits for plant population may be needed for particular environments.

While we had hoped to see some system benefits of the higher density crops for subsequent water accumulation, we have yet to show any of these experimentally. Hence, it seems that management to increase crop competition for weeds is probably best targeted in situations where weed control is problematic, and this approach has not yet revealed any other clear system or carry over benefits for subsequent crops.

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