Effects of row spacing and row placement on grain yield in a sorghum/wheat sequence under high rainfall

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Abstract
Sorghum is an important summer crop of the northern NSW farming system and can provide a break to cereal disease and can control problem weeds. Row spacing in sorghum ranges from 40cm (high potential yield) to > 1m with skip or double-skip rows as options. Inter-row sowing has also been shown to reduce the impact of crown rot and increase yield in a wheat-wheat sequence.
A replicated trial sown at Tamworth, consisted of a wheat-long fallow-sorghum-long fallow-wheat sequence. In 2008, all wheat plots were inoculated with the crown rot fungus resulting in a disease incidence of 25%. Sorghum was sown into standing stubble either on or between the rows at three row spacing (40, 80, or 40 cm double skip-rows). Wheat was then cropped in 2011, sown on or between the old wheat rows.
The solid plant sorghum (40cm rows) had the highest sorghum yield (5.5 t/ha), however, the highest 2011 wheat yield was on the double-skip row sorghum sequence (5.4 t/ha). Row placement resulted in much lower but still significant yield differences with sorghum sown over the 2008 wheat rows having a 5% yield advantage compared to inter-row sowing. However, the 2011 wheat crop sown into the inter-row space relative to the 2008 wheat crop resulted in only a 3% yield benefit compared to on-row sowing. Under high potential sorghum yields, the choice of sorghum row configurations and row placement strategies for both sorghum and the following wheat crop needed to be considered.

Key Words
Sorghum, wheat, row placement, row spacing

Introduction
Sorghum is an important summer crop component of the northern NSW farming system. Traditionally it is grown on a long fallow following wheat then long fallowed out to a durum or bread wheat crop. It can provide a break to cereal disease and can control problem weeds. Row spacing in sorghum varies enormously and increases as potential yield declines. High yielding sites (> 4 t/ha) can have row spacing from as low as 40-60cm while low yielding sites (< 3 t/ha) are generally planted with row configurations > 1m with skip or double-skip rows as options (Serafin and McMullen, 2011).
Inter-row sowing has been shown to reduce the impact of crown rot and increase yield in a wheat-wheat sequence and there was a need to examine whether the effect of row spacing and placement of sorghum and wheat crops would result in differences in grain yield in a four year crop sequence.

Methods
A four year crop sequence experiment consisting of, wheat/long fallow/sorghum/long fallow/wheat was established in 2008 at the Tamworth Agricultural Institute (TAI). The long fallows were of 12 months duration. The TAI site consists of a brown vertosol with an average summer and winter rainfall of 400 mm and 280 mm, respectively, and is regarded as a high sorghum yield potential site. Durum wheat (cv. EGA Bellaroi) was sown in 2008 (40cm row spacing) and inoculated with a low level of the crown rot (CR) fungus, *Fusarium pseudograminearum* at a rate of 2.0 g/m row. Long fallowed in 2009, sorghum was sown into standing wheat stubble in 2009/10 at three row spacings; 40 cm narrow row (NR), 80 cm wide row (WR) and 40 cm double skip-row with1.2 m between paired rows (DS), either on or between the 2008 wheat rows. Long fallowed in 2010, durum (cv EGA Bellaroi) was sown in 2011 at 40cm row spacing either on or between rows relative to the row location of the 2008 wheat crop. Plots were 4m wide by 12 m long with the centre 2 m harvested for grain yield and sampled for pathology assessment.
Both the wheat and sorghum were sown with Janke coulter-tyne-presswheel parallelograms along with 100 kg N/ha and 10 kg P/ha.

Results
The 2008 wheat plots were inoculated with the CR fungus resulting in a disease incidence averaging 25%. This wheat residue was left standing in a long fallow (12 months duration) through to the sowing of the 2009/10 sorghum crop.

The NR sorghum had significantly higher yield (5.47 t/ha) than either WR (4.71 t/ha) or DS (4.76 t/ha) configurations (see table 1)

Table 1. Effect of sorghum row spacing and row placement on sorghum yield (t/ha).

Row Placement	Sorghum Row Spacing Narrow (40 cm)	Wide (80 cm)	Double-skip (40 & 120 cm)	Mean Row Placement (s.e. ± 0.091)
On 2008 wheat row	5.57	4.78	4.93	5.09**
Between 2008 wheat row	5.38	4.74	4.50	4.87**
Mean Sorghum row space (s.e. ± 0.111)	5.47**	4.71	4.76	

** P<0.01, *P<0.05

Sorghum yields were marginally higher when sown directly over the 2008 wheat rows (5.09 t/ha) compared to being sown between the 2008 wheat rows (4.87 t/ha) (see table 1).
Wheat was sown across the trial block in 2011 after a twelve month long fallow. There were twelve (12) treatment combinations tested in 2011 consisting of sorghum row spacing (3) x sorghum row placement (2) x wheat row placement (2). The highest wheat yield was attained on the DS configuration (5.4 t/ha) with the WR and NR sorghum systems having lower wheat yields of 4.5 t/ha and 3.8 t/ha, respectively (see table 2).

Table 2. Effect of sorghum row spacing in 2009/2010 and row placement of wheat in 2011 on wheat yield (t/ha).

Row Placement	Sorghum Row Spacing Narrow (40 cm)	Wide (80 cm)	Double-skip (40 & 120 cm)	Mean Row Placement (s.e. ± 0.054)
On 2008 wheat row	3.75	4.38	5.33	4.49*
Between 2008 wheat row	3.86	4.56	5.40	4.61*
Mean Sorghum row space (s.e. ± 0.066)	3.81**	4.47**	5.37**	

** P<0.01, *P<0.05

Row placement resulted in significant wheat yield differences although much lower than the effect of sorghum row spacing. Sowing wheat into the inter-row space, relative to the 2008 wheat crop, resulted in marginally higher wheat yields (4.61 t/ha) compared to sowing on the old wheat row (4.49 t/ha).
Fallow recharge was adequate with a full profile available at sowing across all sorghum systems.
Grain yield was not nitrogen limited with wheat protein exceeding 12.0% (Russell 1963; Strong 1981) in all treatments. Wheat protein was lowest following NR sorghum (12.5%) and increased at WR and DS configurations with protein contents of 12.7% and 12.8%, respectively (see Table 3).
This translated into grain nitrogen removal rates of 83 kg N/ha, 99 kg N/ha and 120 kg N/ha for NR, WR and DS, respectively (data not shown).

Table 3. Effect of sorghum row spacing in 2009/2010 and row placement of wheat in 2011 on wheat protein (%).

Row Placement	Sorghum Row Spacing Narrow (40 cm)	Wide (80 cm)	Double-skip (40 & 120 cm)	Mean Row Placement (s.e.±0.043)
On 2008 wheat row	12.66	12.70	12.80	12.72**
Between 2008 wheat row	12.38	12.65	12.75	12.59**
Mean sorghum row space (s.e.± 0.052)	12.52**	12.68**	12.78**	

** P<0.01, *P<0.05

Sowing sorghum then wheat into the same rows resulted in the lowest wheat yield (4.41 t/ha) compared to other row placement combinations such as sorghum-on-row + wheat-between-row (4.64 t/ha) (data not shown).

Conclusion

In this environment (high yield potential) NR sorghum (40 cm) resulted in the highest yield (5.5 t/ha) compared to WR and DS configurations (av. 4.7 t/ha) which could be regarded as an above average summer rainfall season in 2009/10.

The biggest influence on the following wheat crop was the row spacing configuration of the previous sorghum crop. By sowing sorghum in a DS arrangement resulted in a 1.0 t/ha yield advantage to the following wheat crop over WR sorghum and 1.6 t/ha over a NR configuration. Wheat protein contents above 12% suggest that the water limited potential wheat yield was not inhibited by the amount of available nitrogen. However, it was clear that the wheat following the NR sorghum had access to 40 kg less nitrogen than wheat following the DS sown sorghum.

The worst wheat yield outcome was attributed to a row placement system that kept sowing over the same row, year after year (4.41 t/ha). The best row placement combination was sowing sorghum over the 2008 wheat rows then sowing the 2011 wheat crop into the inter-row space (4.64 t/ha), meaning the crop was sown into ground that did not have wheat sown in it for at least four years. This inter-row sowing strategy resulted, on average, in a 3% wheat yield advantage over continuous on-row sowing. This is less than the 9% yield advantage reported by Verrell *et. al*. (2005) in a chickpea/wheat/wheat system, but still supports the finding that inter-row sowing can provide a yield advantage to wheat.

Under high potential sorghum yields, the choice of sorghum row configurations and row placement strategies for both sorghum and the following wheat crop need to be considered in order to maximise yields and limit the impact of crown rot on wheat.

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