The effect of row configuration on yield reliability in grain sorghum: 1. Yield, water use efficiency and soil water extraction

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Abstract

Four detailed field experiments were conducted in the Goondiwindi district over the summers of 2000/2001 and 2001/2002 to examine the effects of row configuration on yield, yield components, biomass production, canopy architecture and light interception, water use and patterns of soil water extraction in grain sorghum. Grain yield in skip row treatments was equal to or greater than that of solid plant treatments at yield levels below about 2.5 t/ha. Soil water measurements confirmed that this effect was due to the conservation of soil water in the centre of the skip areas for use by the crop after anthesis. A root front velocity of 2cm/day was observed in all directions from the base of the sorghum plant. Light interception in skip row configurations was shown to be the same as in solid plant configurations between pairs of rows and up to 50 cm into the skip area. Further into the skip area, light interception was effectively nil. These results provide the basis to refine the APSIM Sorghum model to allow simulation of the effect of various row configurations over a range of climatic and soil conditions.

Key Words

Skip-row, crop soil water relations, APSIM

Introduction

Dryland grain sorghum production in the more marginal (<600 mm annual rainfall) cropping areas of Qld and NNSW has been characterised by poor yield reliability. In seasons with low in-crop rainfall, soil moisture reserves are often fully utilised by anthesis and low yields or total crop failure can result. In recent years some producers have adopted 'skip row' configurations as a risk management measure aimed at improving yield reliability. Skip row configurations commonly used include single skip (SS) where every third row is not planted, and double skip (DS) where two rows are planted and two not planted. A base row spacing of 1.0 m is commonly used in the solid planted (SP) configuration.

Skip row configurations are thought to improve yield reliability by delaying utilisation of soil moisture in the centre of the skip area until late in the growing season when the soil water extraction front extends into this area. As a result, soil moisture in the centre of the skip is more likely to be available during the grain filling stage allowing higher yield and increased harvest index in moisture limited growing conditions. In growing conditions with more favourable moisture, skip row yields are likely to be less than SP yields due to the reduced crop leaf area and associated light interception and likely greater soil evaporation.

Butler et al. (1) reported comparative yield for sorghum grown in SP, SS and DS configurations in a number of on-farm trials conducted in northern NSW and southern Qld (Figure 1). These data indicated that SP and skip configuration yields converge at around 2.5 t/ha, although due to relatively favourable seasons during the period when these trials were conducted (1998-2000), few yields less that 2.5 t/ha were obtained.

In order to evaluate the potential risk management benefits of skip-row planting configurations throughout the sorghum production area, a modelling approach allowing simulation over a broad range of seasonal and soil conditions would be effective. However, currently the APSIM sorghum model is incapable of simulating skip row configurations as both soil water extraction and light interception routines are one dimensional, assuming a solid planting configuration. (2,3)

The field experiments reported in this paper were conducted to (i) further quantify the effects of row configuration on yield, yield components and biomass production in sorghum, and (ii) generate detailed data for development of relationships to facilitate modelling of light interception and patterns of soil water extraction in sorghum grown in various skip row configurations.

Methods

Four detailed field experiments were conducted in the Goondiwindi district (Table 1).

Table 1. Site and experiment details. DAS=Days After Sowing.

Experiment	1	2	3	4
Site	Croppa Creek	Billa Billa	Bungunya	Billa Billa
Soil Type	Grey Vertisol	Grey Sodosol	Red Sodosol	Grey Sodosol
Planting Date	6.11.00	13.11.00	28.09.01	5.12.01
Anthesis Date	14.01.01 (69 DAS)	7.02.01 (86 DAS)	13.12.01 (76 DAS)	11.02.02 (68 DAS)
Maturity Date	21.02.01 (107 DAS)	16.03.01 (123 DAS)	14.01.02 (108 DAS)	20.03.02 (105 DAS)
Established Plant Population	75 000 plants/ha	81 000 plants/ha	46 000 plants/ha	77 000 plants/ha
In Crop Rain	409 mm	324 mm	165 mm	253 mm
Treatments	SP,SS,DS	SP,SS,DS	SP,SS,DS	SP,DS

All experiments used a randomised block design with three replicates. The crops were sown and managed by the farmer co-operators as normal commercial crops. Plant populations remained constant across all treatments, resulting in a higher within-row density in skip row treatments. The hybrid used in all experiments was MR Buster.

Soil water content was measured weekly from 2 to 3 weeks after sowing until maturity using a neutron moisture meter. Access tubes were installed midway between the planted rows, on the row, and at 50 cm intervals to the centre of the skip in the skip treatments. Readings were taken at 20 cm intervals down the profile from 20 cm to 160 cm with gravimetric sampling of the surface 10 cm.

Cumulative Water Use (CWU, mm) was calculated at anthesis and physiological maturity as (soil water content (SWC, mm) at the first post sowing measurement – SWC at the relevant growth stage + rainfall).

Water use efficiency (WUE, kg/ha/mm) was calculated as (Grain Yield (kg/ha)/(CWU at physiological maturity).

Plant biomass was measured at floral initiation, midway between floral initiation and anthesis, anthesis, and physiological maturity. At maturity grain yield was determined by threshing heads from 10 metres of row in the first season, and by harvesting a strip by commercial header in the second season. Harvested grain yields were standardised to 13.5% moisture content.

Daily radiation interception was measured using Delta T tube solarimeters, which were placed at 45? to the row so that each sensor measured 50 cm of width relative to the row. Solarimeters were placed in one rep only to measure an entire configuration unit for each row configuration. Therefore in the skip treatments radiation interception was measured in 50 cm increments from the centre of two planted rows to the centre of the next two planted rows.

Results

The effects of row configuration on grain yield, harvest index, total crop water use and water use efficiency are summarised in Table 2. In experiment 1, grain yield was significantly lower in DS, while in the lower yielding experiments there were no yield differences, or SS and DS out-yielded the SP treatment. This trend was consistent with the relationship found by Butler et al (1) as illustrated in Figure 1.

Harvest index was consistently higher in the SS and DS treatments than the SP treatment, suggesting better conversion of accumulated biomass to grain yield, possibly due to greater soil water reserves being available during the grain-filling stage in these treatments. This explanation is supported by values of CWU at anthesis, which were significantly higher in the SP treatments in Experiments 1 and 3.

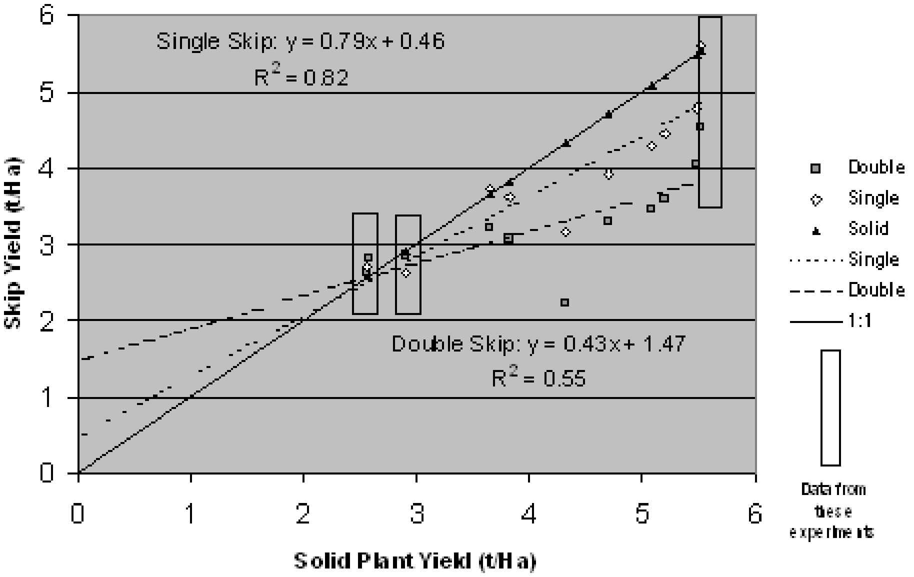

Figure 1. Relationship between Solid plant yield and Skip Yield (adapted from (1)), including data from these experiments.

There were no significant differences in CWU at maturity or WUE among any treatments in any of the experiments, suggesting that the extra soil water available at anthesis in the DS and SS treatments in experiments 1 and 3 was exploited during grain filling.

Table 2. Effect of row configuration on grain yield, harvest index, crop water use and water use efficiency in the four experiments. Within an experiment, values followed by different letters are significantly different at $p<0.05$.

Experiment	Treatment	Grain Yield (t/ha)	Harvest Index	CWU at anthesis (mm)	CWU at maturity (mm)	WUE (kg/ha/mm)
1	SP	5.53a	0.44a	168a	350a	15.8a
	SS	5.60a	0.49b	137b	338a	16.7a
	DS	4.54b	0.49b	135b	327a	13.9a
	Mean	5.22	0.47	147	338	15.5
2	SP	2.91a	0.34a	167a	311a	9.4a
	SS	2.63a	0.40b	155a	301a	8.7a
	DS	2.85a	0.42b	161a	305a	9.4a
	Mean	2.80	0.39	161	306	9.2
3	SP	2.62a	0.41a	199a	291a	9.0a
	SS	2.74b	0.46b	165b	277a	9.9a
	DS	2.63a	0.49c	145c	252a	10.5a
	Mean	2.70	0.45	169	273	9.8
4	SP	2.57a	0.33a	166a	236a	10.9a
	DS	2.81b	0.47b	181a	255a	11.0a
	Mean	2.70	0.40	174	246	11.0

Figure 2 illustrates the effect of row configuration on light interception at one of the sites. The fraction of light intercepted up to 50 cm into the skip area was similar to that intercepted in the solid plant configuration. At distances further away from the planted row light interception was negligible in the skip configurations. A similar pattern was found in all experiments.

The progression of the soil water extraction front through the soil profile in the DS treatment in Experiment 1 is illustrated in Figure 3. The lines indicate the maximum depth of soil water extraction at each point in time (DAS = days after sowing) for each position across the DS configuration. Average root front velocity between sowing and the cessation of root growth can be estimated as the average extraction front velocity over the same period. This method allows for the advance of the root front ahead of the extraction front in the early stages of crop growth. Preliminary analysis of these data from all treatments in all experiments indicated that an average root front velocity of 2 cm per day occurred at all angles from the base of the plant in the row.

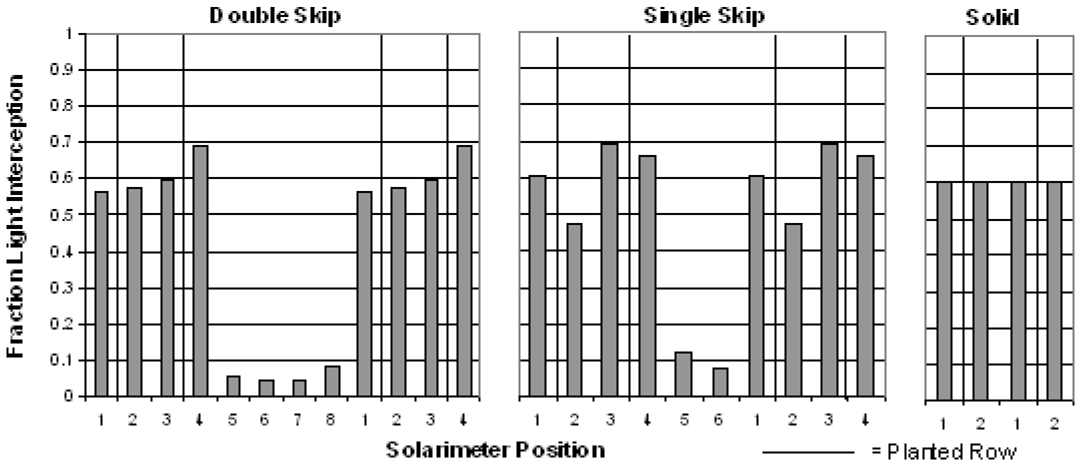

Figure 2. Effect of row configuration on light interception (Experiment 3).

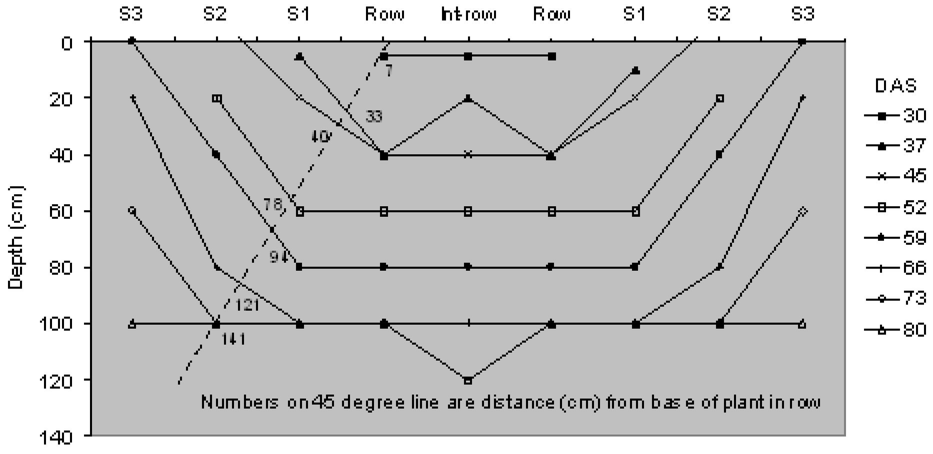

Figure 3. Movement of soil water extraction front in DS treatment, Experiment 1.

Conclusion.

Results from these experiments confirm the hypothesis that skip row configurations can result in increased yields compared with solid plant configurations at yield levels below about 2.6 t/ha and that this effect is due to conservation of soil water in the centre of the skip area for use by the plant in the grain filling stage. At higher potential yield levels, a yield reduction can occur with skip row configurations and the choice of row configuration for a particular paddock situation will depend on available soil moisture at planting, likely in crop rainfall and the producer's attitude to risk. Analysis of data on light interception and water extraction provide a basis to improve the capabilities of the APSIM Sorghum model, thus allowing comprehensive evaluation of the role of skip row configurations for grain sorghum production systems in marginal rainfall environments. McLean et al (4) report initial modelling and simulation studies in the companion paper.

References

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