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The effect of row configuration on yield reliability in grain sorghum: II. Modelling the effects of row configuration

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Abstract
In recent years many sorghum producers in the more marginal (<600 mm annual rainfall) cropping areas of Qld and northern NSW have utilised skip row configurations in an attempt to improve yield reliability and reduce sorghum production risk. But will this work in the long run? What are the trade-offs between productivity and risk of crop failure? This paper describes a modelling and simulation approach to study the long-term effects of skip row configurations. Detailed measurements of light interception and water extraction from sorghum crops grown in solid, single and double skip row configurations were collected from three on-farm participatory research trials established in southern Qld and northern NSW. These measurements resulted in changes to the model that accounted for the elliptical water uptake pattern below the crop row and reduced total light interception associated with the leaf area reduction of the skip configuration. Following validation of the model, long-term simulation runs using historical weather data were used to determine the value of skip row sorghum production as a means of maintaining yield reliability in the dryland cropping regions of southern Qld and northern NSW.

Key words
Sorghum, skip-row, row configuration, simulation, modelling, light interception, water extraction

Introduction

In the marginal cropping regions of northern NSW and southern Qld, the production of sorghum in skip row configurations has been considered (9,2) as a means to manage risk. Current grower experiences indicate that losses are minimised with double skip planting, however potential yield is often less than with conventional solid planting. James Clark, a sorghum grower at Croppa Creek in northern NSW sums it up as "*So far the potential is that I can't make a loss with double skip planting, but I can't make as big a profit*".
In order to study the influence of row spacing on production risk, multiple seasons and sites are needed as climatic conditions and rainfall patterns are highly variable from season to season. A field research program to generate this data would be prohibitively costly and take many years to complete. Alternatively simulation modelling in conjunction with smaller field based data sets offers an efficient and effective way to study the influence of row spacing on production risk. This paper describes modifications made to the APSIM-Sorghum module to enable it to simulate sorghum crops grown in skip row configurations. The new model was then tested against detailed field trials established in the sorghum production areas of northern NSW and southern Qld. Long term

simulations comparing risks for different sorghum row configurations are presented.

Methods

Model development

The current APSIM-Sorghum model was developed from the QSORG model (6) with features of the AUSIM model (3) and recently adapted into the APSIM-crop module template (10). The current sorghum module estimates light interception with a whole plant leaf area approach (5). This method of estimating leaf area index (LAI) is analogous to the Beer-Lambert law, and assumes a random horizontal distribution of leaf area. In simulating skip row sorghum the assumption of a horizontally distributed leaf area does not hold. To account for this the equation for calculating the percentage green cover of the plant is changed from equation 1 to equation 2

Eq1 %green cover = $1-\exp(-kl)$ where k is the extinction coefficient of the crop at that row spacing and l is the leaf area index

Eq2 % green cover = $\frac{1-\exp(-KLS)}{S}$ where k is the extinction coefficient of the crop at that row spacing, l = is the leaf area index and s is the skip index (1 for no skipped rows, 1.5 for one skipped row, and 2 for two skipped rows)

The second change to the APSIM sorghum module was a modification to the root expansion front. The existing method of root expansion is described by Robertson and Fukai (1994) and utilises a uni-directional approach that has roots filling soil layers and expanding only in a downward direction. It was believed that with the skip configuration the wide gap between plants meant that root expansion needed to be multi-directional, allowing time for the roots to reach the centre of the skip rows. Experimental results (9) showed that the root expansion front could be described by a semi circular front expanding from the base of the plant at a rate of 2 cm per day in all directions.

Model testing

The model was tested against observed data collected from three detailed experiments conducted in northern NSW and southern Qld and described in detail by Routley *et al.* (2003). For each observed data set the APSIM skip row sorghum model was parameterised as described in Table 1. Soil characterisation data were available to parameterise the soil at each site (1).

Table 1 Parameters used for the skip sorghum model validation.

Site	Croppa Creek 2000			Billa Billa 2000			Billa Billa 2001	
	solid	single	double	solid	single	double	solid	double
Row spacing (m)	1	1	1	1	1	1	1	1
Sow date	6/11/00	6/11/00	6/11/00	13/11/00	13/11/00	13/11/00	5/12/01	5/12/01
Starting water (mm)	365	365	365	304	304	304	386	386
Starting nitrogen (kg/ha)	225	225	225	217	217	217	97	97
Plant density (plants/m^2)	7.7	7.2	7.5	8.5	8.2	7.5	7.8	7.6
Fertile tiller number (tillers/m^2)	0.25	0.11	0.18	0	0.04	0.06	0	0

Long term simulations

Long term simulations were conducted based on a Dulacca Brigalow/Belah medium clay with a plant available water holding capacity of 160 mm. Long-term meteorological data was obtained from the Dulacca weather station. The starting water for the simulations was either a full or 2/3 full profile with non limiting nitrogen.

Results and Discussion

Model testing

The simulated results for the three row configuration treatments matched the data for each trial well (Fig.1). The model appeared to slightly under-predict grain yield and biomass for higher grain yields. Further studies are needed to confirm these findings, as the sample size used in this study was small. Simulated soil water content correlated well with the observed soil water content from single and double skip row configurations (Fig. 2). The simulated response to the large rainfall event that occurred approximately 90 days after sowing was less than the observed response. This may be explained by water moving down cracks around the neutron probe tubes providing an artificially high reading.

Long-term simulations

The simulation results indicated that when planting sorghum on a full profile, the use of a double skip configuration generally produced grain yields less than that for a solid configuration (Fig. 3). In contrast, when the starting soil profile was 2/3 full, the double skip configuration resulted in higher grain yield than solid planted sorghum in 45% of years. It was estimated that double skip planting was advantageous when grain yield of the solid configuration was less than 2.5 t/ha. This was consistent with the experimental findings reported by Butler *et al.* (2001) and Routley *et al.* (2003).

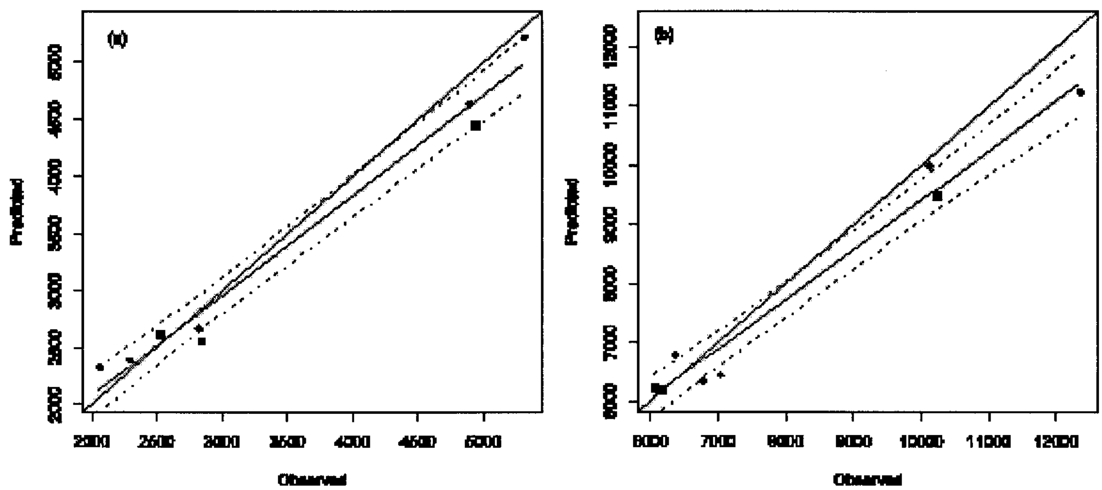

Fig. 1. Observed versus simulated sorghum grain yield (a) and biomass (b) in kg/ha for solid, single, and double skip row configurations. The 1:1 line is included with the linear regression through the points. Broken lines represent the 95% confidence interval. R^2 for sorghum yield = 0.97 and biomass = 0.97. Different symbols represent different row configuration treatments.

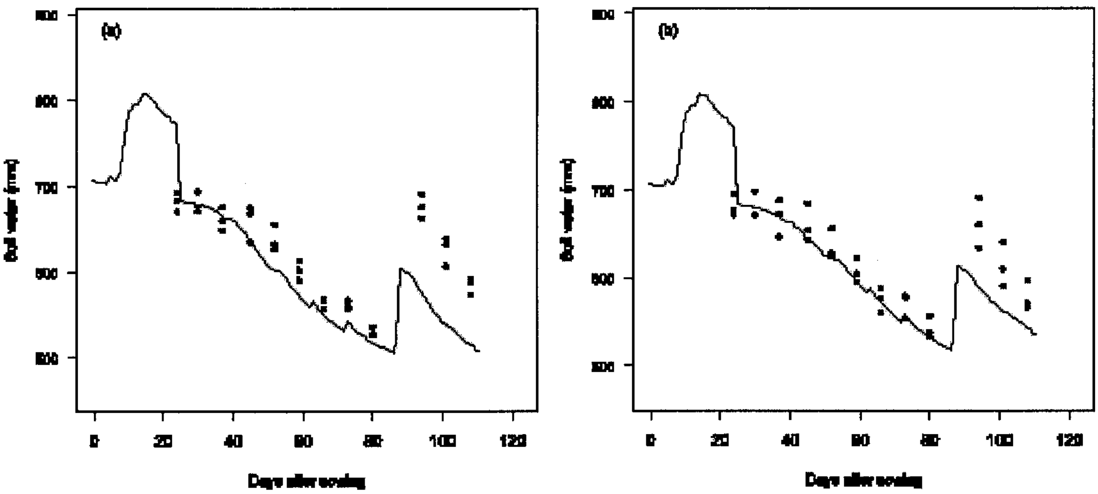

Fig. 2. Observed (points) and simulated (line) soil water for single skip (a) and double skip (b) configurations.

The long term simulations for this specific scenario indicated that the median grain yield from the double skip configuration (2112kg/ha) was slightly higher than that obtained from the solid configuration (2036kg/ha) (Fig 4). However, there was a considerably reduced risk associated with adopting a double skip row configuration. There were no failed crops simulated in the double skip configuration, whereas some occurred with solid planting. The maximum grain yield of the double skip configuration was, however, well below that of the solid configuration. Subsequent research will examine a diverse range of scenarios and incorporate economic analyses of the profit-risk trade-off.

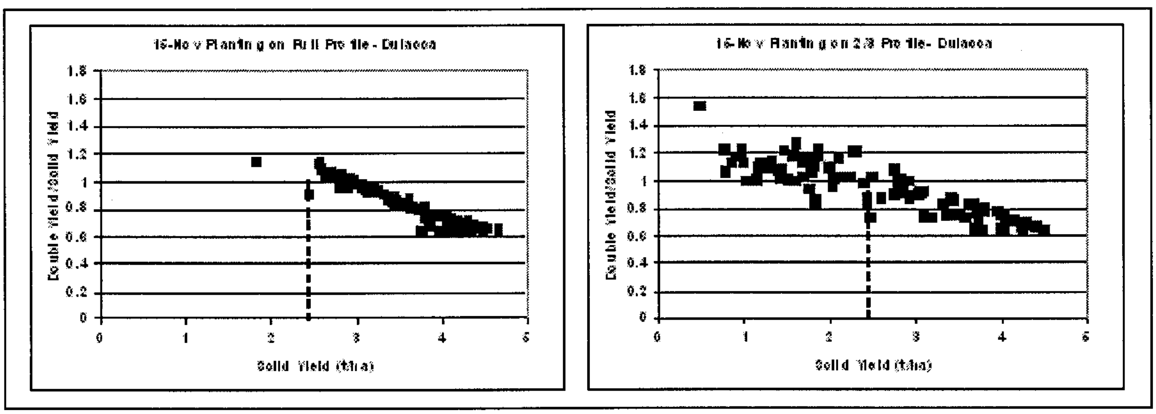

Fig. 3. Ratio of double skip to solid yield versus yield of solid configuration from long term simulation with full and 2/3 full soil profile at planting for Dulacca.

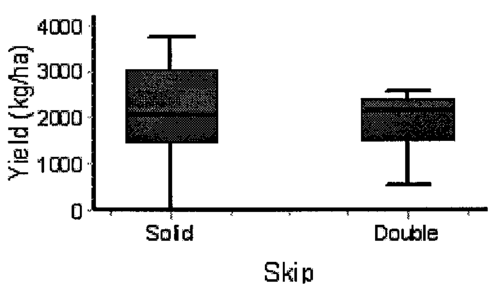

Fig. 4. Long term simulation mean, maximum and minimum grain yields for double and solid skip configurations at Dulacca in southern Queensland.

Conclusion

Skip row sorghum is being adopted by sorghum growers on the western side of the traditional sorghum producing regions and is considered a method for extending sorghum westward into those areas considered marginal for sorghum production. The use of a double or single skip configuration improves the yield reliability of sorghum by reducing failures and capping maximum yield. The long-term value of forgoing this potential yield can only be assessed by long-term studies, or as described in this paper, by simulation modelling. The model described in this paper adequately explained the variation observed in the three field trials examined. The ability to accurately predict sorghum growth in a skip row configuration will benefit farm decisions by helping assess the risk of each configuration with respect to current soil water and long-term climate forecasts. The model also has potential in investigating the value of sorghum as a cropping option in non-traditional sorghum cropping regions.

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