The Effects of Maize Rotation on Soil Quality and Nutrient Availability in Cotton Based Cropping

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Abstract

Rotation crops have been utilized by cotton producers in Australia since the early 1980's for the perceived benefits to soil quality, cotton yield and profitability. The benefits of wheat and legume rotations on cotton crops have been well established. However maize rotation is becoming more popular and has recently become of interest due to anecdotal field evidence of increases in the following season's cotton yields of up to 25%. Compared with continuous cotton cropping, a maize crop with more shoot and root biomass and a shallower root system may provide more organic matter to the soil and extract less water and nutrient from deeper soils, which would benefit the subsequent cotton crop. In order to test these ideas water stress trials were established in the rainout shelters at the University of Queensland Gatton campus. Water stress treatments were imposed 38 and 71 days after sowing. Soil moisture content was monitored using a neutron moisture meter and crop root growth was investigated with soil cores taken consistently throughout the growing season until crop maturity. The results of the prolonged water stress trial showed that maize had higher root mass in upper soil layers, but extracted less water in 30-70cm soil layers.

Key Words

Water stress, soil water, root growth and rotation cropping

Introduction

Continuous cotton cropping is well known to result in reduced soil quality and declining cotton yields (Burnett and Tackett, 1968, Hulme et al, 1991, McGarry and Chan, 1984, Steinhardt, 1976). Crop rotations have been utilized in Australia since the early 1980's for the known soil structural benefits and perceived benefits to soil quality, cotton yield and profitability (Hulme et al, 1991). The benefits of rotation crops in cotton production are well supported by field trials (Hulugalle et al, 2004, Rochester et al, 1998, Rochester et al, 2001).

There are many crop rotations currently utilized by cotton producers including wheat, sorghum, chickpeas, safflower, barley, oats, mungbeans, field peas, faba bean, dolichos lab lab and corn (Cooper, 1993, Hulugalle and Scott, 2006). Although wheat is the primary rotation crop in cotton based cropping systems (Cooper, 1999), legume rotations are also widely spread.

Recently maize rotation has become of interest due to anecdotal field evidence of substantial increases in the following seasons cotton yield. Cotton and maize producers at Dalby and Garah have reported increases of up to 25% in cotton yield after maize rotation (James Holden 2005, pers. comm.). However further investigation is required into the quantitative benefits of maize on cotton yield and quality and overall economic benefits and key soil processes underpinning these benefits in irrigated cotton based cropping system. Potential benefits of maize on the following cotton are better soil physical conditions due to increased biomass from maize roots and shoot residues and higher soil water content available at the time of cotton planting due to earlier harvesting and shallower root systems of maize.

The objective of this study was to quantify soil water extraction of cotton and maize and root distribution in the soil profile to investigate the potential effect of maize in cotton rotation system.

Materials and Methods

A field experiment was conducted at The University of Queensland, Gatton (152?20'E, 27?33'S) which has a sub-tropical climate. The hottest month is January (mean daily maximum of 31.5?C) and the coldest is July (mean daily maximum of 20.7?C). Mean annual rainfall is 769.5 mm. The soil at the experimental site is a light brown Verstisol.

Two water stress trials were established in the rainout shelters with water stress in the form of exclusion of water supply imposed from 38 days after sowing (DAS) (prolonged water stress trial) and 71 DAS (short water stress trial) to maturity. A randomised block design was utilised in each trial with two crops as treatments and four replicates. Cotton (*Gossypium hirsutum*) and maize (*Zea mays* L.) were hand sown on 19 November 2007. Plots were 4 m in length by 6 rows with 1 m row-spacing. Solid-set sprinkler irrigation was used when rainfall and profile storage did not meet crop water requirement before the stress period. The soil water profile was filled with a final irrigation immediately prior to imposing water stress.

A neutron moisture meter, calibrated in situ, was used to measure volumetric soil water contents at 0.3, 0.5, 0.7, 0.9, 1.1, 1.3, 1.5 and 1.7 m depths. One access tube was installed per plot. Measurements were undertaken approximately every two weeks starting before the final irrigation prior to imposing water stress in the rainout shelter trials.

Soil cores of 50 mm in diameter were taken using a tractor-mounted hydraulic soil-coring machine to a depth of 1.8 m. Cores were then broken into 200 mm lengths and cold stored until washing to separate soil and roots and sieved using a 1 mm screen. Root samples were then separated from other organic material and transferred to a dehydrator at 60°C and oven dry weights recorded. Soil coring was conducted approximately every 30 days starting 24 DAS before the final irrigation.

Results and Discussion

Results of water extraction on three occasions and root mass on two occasions for the prolonged water stress trial only, are shown in this paper.

Soil water content was similar in maize and cotton at 24 DAS prior to final irrigation (Fig 1). Soil water content below 90 cm was higher at 65 DAS under both crops than prior to the final irrigation at 24 DAS. Soil water content at 65 DAS was similar under both crops at all depths except 30 cm. Water extraction occurred down to 130 cm between 65 and 92 DAS. Soil water extraction was greater in cotton than maize at 30-70 cm despite cotton having a smaller root mass/ha (Table 1). Therefore cotton was more efficient in water extraction in terms of uptake per gram of root. This is probably related to cotton having a tap root and being more efficient than the fibrous root system of maize, or cotton being more active at the time of sampling either because maize is approaching maturity or because maize is more susceptible to water stress. It is likely that the difference in soil water content under the two crops will be greater at cotton maturity because maize matures earlier than cotton. Thus the soil water available to the following cotton crop will be greater after maize than cotton.

Maize root mass increased greatly between 24 and 65 DAS. Root mass in the 0-40 cm of the soil profile was greater in maize than cotton at 65 DAS (Table 1). The greater maize root mass near the surface may result in increased macropores which aid infiltration. Consequently water availability to the following cotton crop may be improved after a maize rotation.

Values for root mass yield and distribution were similar to those found in the literature (Amos and Walters, 2006, Sainju et al, 2005). Comparable to this study, decreasing root mass with depth was also found by other researchers (Sainju et al, 2005). Previous studies in rotational effects of crop root growth are limited and have generally focused on wheat and legume rotation in terms of nitrogen nutrition (Hulugalle and Scott, 2008, Rochester et al, 1998).

A subsequent experiment was set up at Gatton in the 2007/08 season to further investigate the effect of maize on cotton growth and yield. In this experiment maize shoot and root biomass was varied by growing maize under different plant density and nitrogen fertilizer conditions. Further treatments include retention/removal of maize shoots from the field as well as cotton crop. The effects of various maize root and shoot biomass on root development and water extraction of cotton will be investigated in the next season.

Table 1. The root mass (kg/ha) of cotton and maize under prolonged water stress. (Numbers in brackets are standard error).

	24 DAS		**65 DAS**	
	Maize	**Cotton**	**Maize**	**Cotton**
		kg/ha		
0-20 cm	**95** (37.47)	**393** (228.87)	**1220** (534.49)	**305** (161.78)
20-40 cm	**60.10** (38.58)	**139.80** (65.56)	**391** (56.60)	**141** (16.87)
40-60 cm	**0** (40.49)	**26** (15.44)	179 (22.86)	**79** (50.78)
Total	**239**	**575**	**1875**	**619**

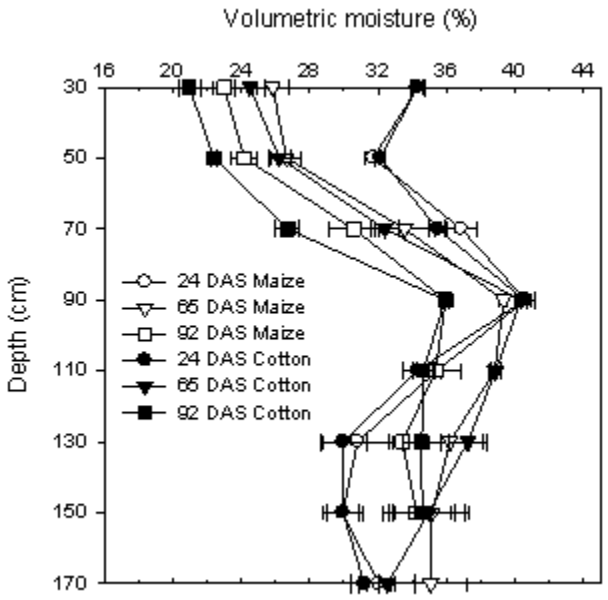

Figure 1. The soil water content of cotton and maize trial with prolonged water stress. Values at 24 DAS are prior to final irrigation.

Conclusion

Maize with greater root mass in the upper profile would result in increased macro pores and consequently increased infiltration which may result in increased water availability to the following cotton crop.

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