EFFECT OF SOIL WATER HOLDING CAPACITY ON COTTON PLANT WATER STRESS

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Abstract

This paper presents results investigating the variation in cotton plant's growth responses to soil water status with different soils types. Such information is necessary to optimise irrigation strategies. Field experiments were conducted on three soil types around Narrabri NSW Australia with plant available water holding capacities ranging from 60 to 200mm. To assess plant response to moisture stress two treatments were also imposed (no stress (no irrigations missed) and stress applied during the period immediately prior to and during flowering (skipping two irrigations)). Measurements of soil water status and leaf water potential (used as an indication of the level of plant stress) were taken during the imposed stress in both stress treatments and throughout the recovery period. To compare data across the three soil types soil moisture measurements were expressed as a fraction of transpirable soil water (plant available soil moisture/plant available water holding capacity).

The response of plants to soil moisture stress across the three soil types was different with the lighter soil (the one with lowest soil water holding capacity) exhibiting greater plant stress at all levels of soil water status. These results highlight the need to establish specific soil moisture stress responses for different soil types. There were strong indications that high evaporative demand was a strong factor in determining leaf water potential, especially in light soils. This research forms part of detailed investigations into soil moisture plant stress responses with prevailing climatic conditions had a large effect on the ability of the plant maintain water status even under low levels of soil moisture deficit, on high evaporative demand days plants often experienced stress which had an impact on yield despite a high proportion of water still being available in the profile.

Introduction

Cotton is grown on a range of soil types with differing water holding capacities in Australia. A large proportion of the soils are heavy clays, but loams and alluvial soils are also used. The water holding capacities of these soils is influenced by: clay content, soil structure, organic matter content, profile depth, sodicity, fertility and compaction. As well as modifying soil water-holding capacities, variation in these factors may also affect how the plant is able to access and use the water from the profile. Understanding how the cotton plant responds to moisture stress on the different soil types will assist in developing tailored water management strategies for a wider range of cotton growing regions that vary in soil types. It may also improve the robustness of the OZCOT cotton simulation model (Hearn, 1994), which utilises the Richie (1972) soil water balance. The model uses a soil moisture stress index approach (plant available soil moisture/plant available water holding capacity) to modify predictions of plant growth on a daily basis (Hearn 1994). The model was developed primarily for use on vertosol soils and assessing how the soil moisture index responds across different soil types may make the model more widely applicable.

Methodology

Experiments were conducted during the 2005-2006 cotton season using three soils with different water holding capacities around Narrabri NSW Australia: very fine self mulching vertosol (heavy), fine self mulching vertosol (medium), and thick brown Kandersol (light) (Isbell 1996) (Table 1). The different soil types were located in the same district in order to minimise differences in climate during the season. The experiments used the variety Sicot 289BR (CSIRO, Australia) and used a split plot design with 4 replicates on each soil type. Two irrigation treatments were applied to generate a range of plant stress: optimum, no intentional moisture stress where irrigation was in line with farmer practice, and deficit, skipping two irrigations during the period immediately prior to and during flowering. Measurement of leaf water potential, made using a pressure chamber (Scholander *etal*. 1965) both pre dawn and around midday on the youngest fully expanded leaf on two plants per plot. Soil moisture was measured using a neutron probe, in all plots on the same day.

Soil moisture stress was expressed as the fraction of transpirable soil water (FTSW) (Sinclair and Ludlow 1986) (plant available soil moisture/plant available water holding capacity (PAWC)) calculated from the neutron probe measurements to allow for interpretation of data across the three sites with different water holding capacities. PAWC was estimated as the difference between wettest and driest soil profile for each site.

Table 1. Soil characteristics (plant available water holding capacity (PAWC))

Soil type	PAWC	Sand %	Silt %	Clay %
Thick brown Kandersol (Light)	60 mm	80	5	15
Fine self mulching Vertosol (clay 45 - 60%) (Medium)	130 mm	25	25	50
Very fine self mulching Vertosol (clay >60%) (Heavy)	200 mm	25	15	60

Results and Discussion

Midday leaf-water potential of the cotton plant in relation to the FTSW for all sites is presented in Figure 1.

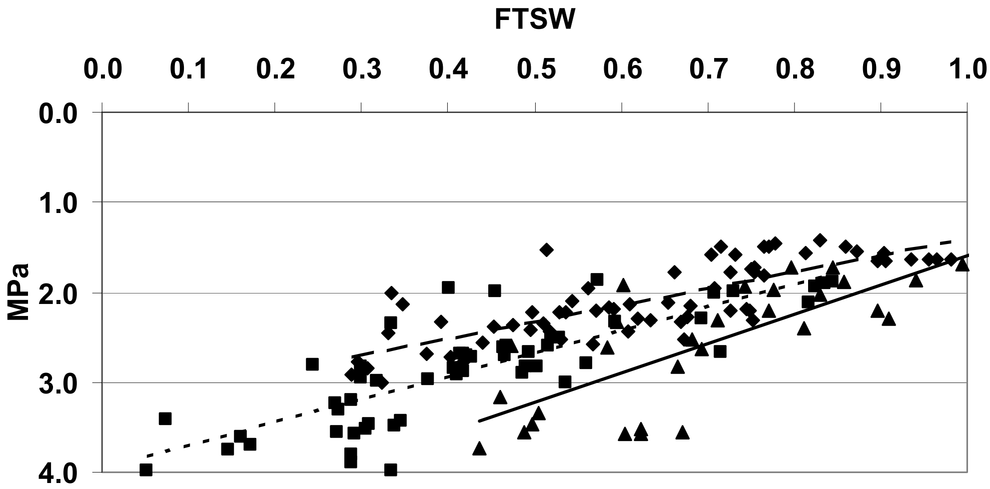

Figure 1. Midday leaf water potential (MPa) vs. fraction of transpirable soil water (FTSW) for three soil types; heavy (♦, dashed line), Medium (■, dotted line), and Light (▲, solid line).

On all soils, leaf water potential increased linearly with decreasing FTSW in both the pre dawn (data not presented) and midday measurements, however these responses differed significantly across the three soil types. On the light soil type, plants exhibited greater stress at corresponding FTSW's than in the medium soil and the medium had greater plant stress than the heavy soil type. On average, leaf water potential of -2.0 MPa occurred at 0.69 FTSW on heavy soils; at 0.76 FTSW on medium soils; and at 0.87 FTSW on light soils. These results indicate that for accurate irrigation schedules, there is a need to assess these responses for varying soil types.

Previously it has been reported that the leaf water potential at which the cotton plant becomes stressed is approximately –1.9 to –2.0 MPa (Grimes and Yamada 1982; Hearn and Constable 1984). For the light soil in particular, the high leaf water potential values for 0.5 to 0.7 FTSW were during periods of high evaporative demand. Thus there were indications of plant stress even when water was readily available to the plant. Pinter and Reginato (1982) for cotton found that plant moisture stress was highly correlated with atmospheric vapor pressure deficit. Further research is investigating the effect of climate on plant water status over a wider geographical range to elucidate the degree of differences in the response of soil moisture stress to both soil type and prevailing climatic conditions.

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Acknowledgements

The author would like to acknowledge Ross Gregory for technical assistance, the Cotton Research and Development Corporation and the Cotton Catchment Communities CRC for funding this project.