Soil and climate influence on water relations of the cotton plant

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Summary

Soil type and climate both influence the cotton plants response to soil moisture status. Soil types differ in both the amount of moisture contained and more importantly how this moisture is available to the plant. Climate, through evaporative demand, influences plants requirement for water, mainly through changing evapotranspiration rates. The combination of these two factors has a large effect on the level of plant moisture stress and consequently irrigation scheduling for cotton. Our research investigates the effect of these factors on the cotton plant in the Australian cotton industry and our aim is to refine irrigation scheduling guidelines and promote increased water use efficiency.

Plant water relations

Plant water relations is how plants respond to available water status with changing environmental factors. These responses can occur, over a number of different time frames, and at different levels within a plant. As all plants span 2 different environments, the soil and atmosphere, it is the interaction in plant response to changes in each of these environments that will determine plant development, growth and yield. Understanding how a plant will function with its available soil water under varying environmental conditions is a key to understanding the whole system.

The response of a plant to available soil water status is modified in the longer term via a number of pathways and at a number of scales. Research by Cutler and Rains (1977) has documented the capability of cotton to acclimate to drought stress due to previous exposure. Similarly it is well known that stress can induce deeper rooting than a high water supply. It is also recognised that in the shorter term, without these mechanisms acting, there is still an effect of available soil water status on plant response. Denmead and Shaw (1962) showed that the impact of a given water deficit on plant function is greater when the evaporative demand is high. In reviewing the literature on plant response to water status, Sadras and Milroy (1996) showed that plants grown on heavy soils were less affected than those on lighter soils, even when the water status was indexed relative to the capacity of the soil to hold water.

Effect of Soil type

There are a range of soils used in the Australian cotton industry, a large proportion of the soils are black earths and gray clays, but there are also red brown earths and alluvial soils. These soils have a number of factors that affect their water holding capacity including: soil structure, organic matter content, profile depth, sodicity, fertility and compaction. As well as having different water holding capacities different soil types also affect how the plant is able to access the water from the profile.

Clay and sandy soils have a different plant available water threshold at which leaf expansion stops, regardless of the amount of water available in the soil profile. The plant is able to utilize more water out of the clay than the sand because of the rate of extraction of moisture from the soil. In the sand the moisture is initially extracted easily and rapidly from the larger pores and the plant is unable to adapt to the change in matric potential when this easily extracted water is removed. In the clay the plant extracts the moisture more slowly and the plant has time to adapt to the changing matric potential, which occurs more slowly than in the sand, and is therefore able to extract a greater proportion of the available soil moisture. Our research is investigating the effect that this variable water availability, across different soil types and at different levels of moisture stress, has on cotton plant growth and yield. The response of the plant at different stages of growth is particularly important. Determining how the cotton plant responds to moisture stress in a particular soil type is critical for efficient water management.

To research the effect of soil type on the plant water relations of cotton, experiments have been conducted in the field on three different soil types gray clay, lighter clay and a sand overlying a clay. Different soil types in close proximity to each other were selected to ensure that climate was constant across the experiment and soil factors were the major difference between the sites. The response of plants was measured under a range of irrigation treatments, especially moisture stress during the period prior to flowering of the plants, growing in the three soil types. Measurements of leaf water potential, soil moisture, leaf expansion rate, yield and fibre quality were conducted. Measurement of leaf water potential was conducted using a pressure chamber, readings were taken both pre dawn and midday to determine minimum and maximum plant stress. As leaf water potential measurements are destructive, measurement of leaf expansion rates are being investigated as a means of measuring plant stress, as cell expansion is sensitive to soil moisture deficit.

Effect of evaporative demand

Climate climatic factors such as relative humidity and temperature can influence the demand for moisture that is placed on the crop. Different levels of evaporative demand will change the water potential of the plant at the same level of soil moisture deficit. In fact under high evaporative demand the cotton plant can experience short periods of moisture stress even when the water supply in the soil is at close to field capacity (Krieg 2000). Figure 1 shows the effect that evaporative demand has on the leaf water potential of cotton. Under two different conditions of evaporative demand, average and hot, for a given level of available soil water the plant under the hot conditions has a higher leaf water potential and consequently is under greater stress. It is reported that the leaf water potential at which the cotton plant becomes stressed is approximately –20 bar (Hearn and Constable 1984), this is called the irrigation point. In this example at the irrigation point the plant under the average conditions only has 55% available soil moisture but the plant experiencing the hot conditions still has 60% available soil moisture for the same level of plant stress. The greater the evaporative demand the higher soil moisture content at which you will have plant stress occurring.

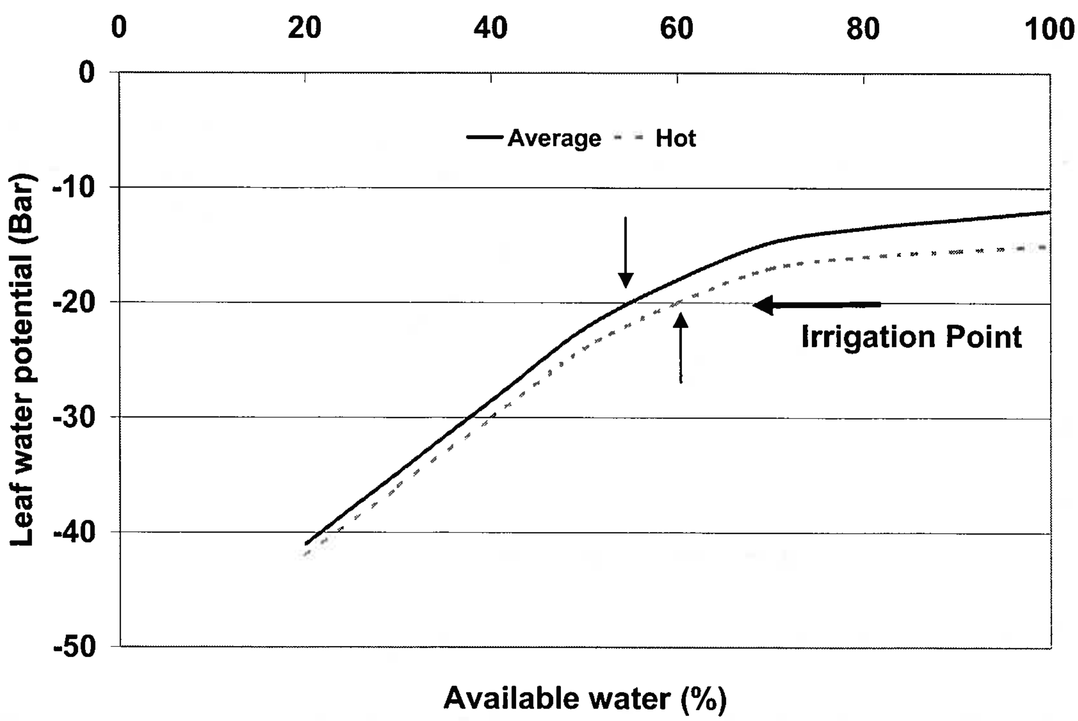

Figure 1. Plant leaf water potential vs. available soil water in two evaporative conditions.

Combined effects

The main aim of our research is to combine the work investigating the effect of soil type and climate to integrated irrigation management techniques. This information will be included in the irrigation management tool HydroLOGIC, which will provide the ability to fine tune irrigation scheduling for all growing regions. The combined effect of soil type and evaporative demand on the level of plant water stress and therefore irrigation timing can be large. Figure 2 shows the combined effect of a clay and sandy soil with average or hot conditions. It shows that there can be a large difference of up to 12 days in the requirement for irrigation of the cotton crops for the same level of plant stress at the irrigation point. This difference has large consequences for irrigation strategy in the difference cotton growing regions, and even at the smaller scale with different soil types on farm.

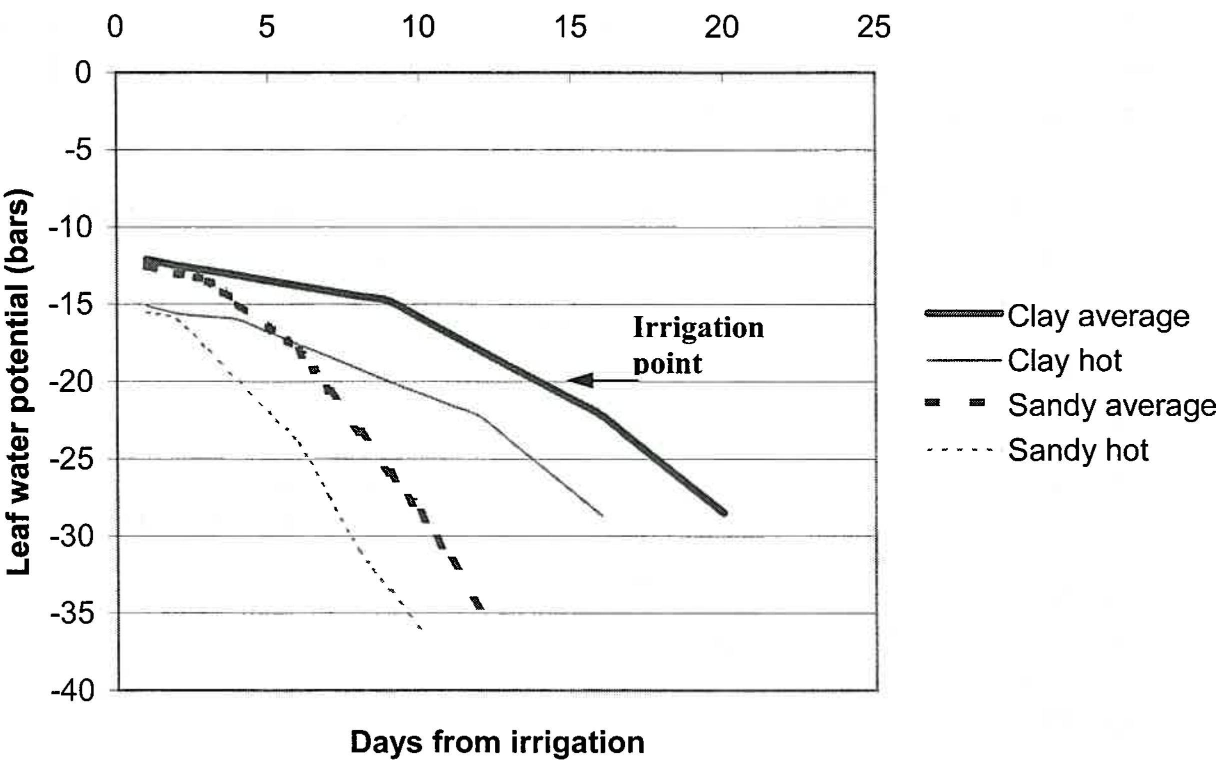

Figure 2. The effect of soil and evaporative demand on leaf water potential

This research aims to quantify the impact of variation in soil type and atmospheric humidity in the cotton growing regions on the response of cotton to water status. This will assist in developing more robust water management strategies for a wider range of cotton growing regions and may also contribute to the development of better genotypes.

References

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