Waterlogging and Its Effect on Cotton Growth and Yield

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Waterlogging is an important cause of yield loss on the cracking grey clays. We conducted a field experiment to quantify its impact on growth and yield. In terms of management, the results demonstrates the importance of ensuring adequate bed height and allowing excess water to leave the field quickly, definitely not later than 48 hours after irrigation.

Introduction

In Australia, cotton is generally grown using furrow irrigation on cracking grey clays with slow drainage, and is therefore usually subjected to some degree of waterlogging. This problem is made worse by imperfect land preparation or by rainfall after irrigation. Yield reduction of 10 to 40% have been reported (Hodgson & Chan, 1982), resulting in millions of dollars annual loss to farmers (Dennis et al, 2000). Therefore, ameliorating this problem would be highly beneficial to the industry.

Waterlogging, is a major complex environmental stress. The term 'waterlogged' or 'flooded' is normally used to indicate the unfavourable aeration status of the soil with excessive water levels, leaving little or no room for gases especially oxygen (Brady, 1984; Marschner, 1995). The major & immediate effect of waterlogged soils on plant growth is a deficiency of O_2 required for root respiration and growth. (Letty et al, 1962; Brady, 1984; Marschner, 1995). This happens because gases diffuse 10,000 times more slowly in water than in air (Armstrong, 1979). Hence, soil oxygen supply from the atmosphere is reduced while other toxic gases, such as carbon dioxide, ethylene or methane, accumulate to high levels (Smith & Russell, 1969; Brady, 1984; Soffer et al, 1989; Marschner, 1995).

At present, cotton computer models, such as OZCOT, contain very simple physiological information about the plant's response to waterlogging. A. Hodgson & G Constable did significant research on this topic during 1975-1990, but more information is still needed.

The basic questions when you see free water lying in a cotton field are a) will I get waterlogging? and b) will my cotton suffer yield loss?

The experiment

To answer these questions, a field experiment was conducted last summer at ACRI, Narrabri. Sicala V2*i* and NuCotton37 were planted on low (5cm) and normal (15) cm ridges and received either normal irrigation with 8 hrs running water, or were subjected to inundation for 52 hrs to 72 hrs at each irrigation. Five waterlogging events were imposed, starting from 16 December 1999. These events were repeated every 2 weeks, each according to the normal irrigation scheme, until 1 March 2000. Sequential measurements were made of soil O_2 at 15 cm depth and soil water at 10 cm depth intervals to 120 cm on the day before and 1, 2, 3, 5, 7, 14, and 21 days after each waterlogging event. Plant biomass was sampled on the day before and 7, 14 and 21 days after irrigation. Hand picked yield and total bolls per metre were harvested at the end of the season.

The answers to date

A) When will waterlogging occur?

Fig. 1A, 1B and 1C show the change over time in the oxygen concentration at 15 cm, the soil water content in the top 10 cm, and soil water in the whole profile of 120 cm depth. Changes in soil water content and oxygen concentration depended mostly on the period of inundation. With 52 hrs inundation in the first irrigation, the surface of the waterlogged plots received about 25 mm of water, about 10 mm higher than the non-waterlogging control. This was not enough to saturate the whole profile or to cause a significant difference in profile water content between the waterlogged and non-waterlogged treatments. In the following irrigations, inundation periods of the waterlogged plots were increased to 72 hrs which increased the period for which the profile was saturated.

Although the soil O_2 decreased rapidly from the beginning of irrigation, it was not completely depleted until about 48 hours after inundation in the waterlogged plots. This time-lag might be explained by the fact that even when all the soil pores have filled with water, there are still small but significant quantities of O_2 in the soil that can be used by plant roots or soil microoragnisms for metabolism (Stolzy et al, 1961; Stolzy & Letey, 1964; Brady, 1984). If this O_2 is used up prior to the excess water being removed, then root respiration will be jeopardised. The quick increase of soil oxygen immediately after irrigation was ceased indicates that removing excess surface water is an effective way to prevent soil from being waterlogged.

These results suggests that in this cracking clay soil with 1:1500 slope, waterlogging is not likely to occur unless the soil surface is continuously under water, either from irrigation or rainfall, for less than 48 hrs. The quicker the excess water is drained, the less chance there is of waterlogging occurring.

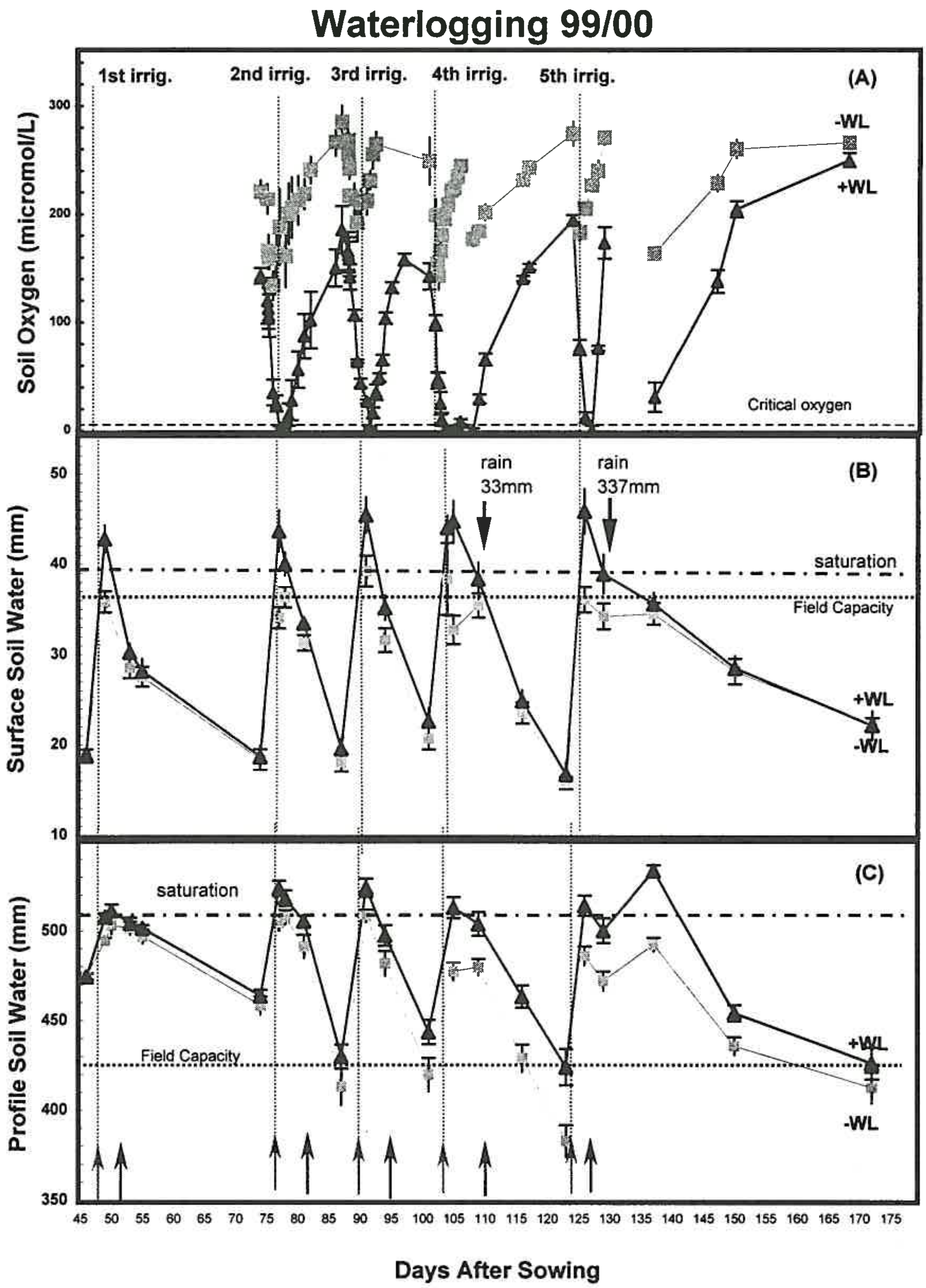

Figure 1 Soil oxygen concentration at 15 cm (A), soil water content in the top 10 cm (B) and soil water in the whole profile to 120 cm depth (C) over time from the first irrigation to the end of the season. Waterlogging experiment, 1999/00. Vertical lines mark beginning of each irrigation while up- arrows mark the end of irrigation, the grey ones for non-waterlogged and the black ones for waterlogged treatments.

B) When will waterlogging effect cotton growth & yield?

The effect of waterlogging on growth and yield depends on the cumulative time that the root system is exposed to an oxygen level less than 0.1%, whether this occurs in a single event or a number of events (Hodgson,1982; Myer et al, 1987). Hodgson (1982) also demonstrated that the yield of cotton started to decline after 2 cumulative days below the critical oxygenation. Our result is consistent with this trend. As derived from Fig 1A, the number of days with oxygen lower than the critical level are 1.5, 1, 5.5 and 0.5 days for the 2nd, 3rd 4th and 5th irrigation respectively. Fig. 2 shows the change in shoot biomass over the season. The difference between waterlogged and non-waterlogged treatments did not occur until after the 3rd irrigation, when growth rate of the control plants increased markedly but that of the waterlogged plants did not. At that time, the cumulative duration under the critical oxygen level was 2.5 days, consistent with the results of Hodgson (1982).

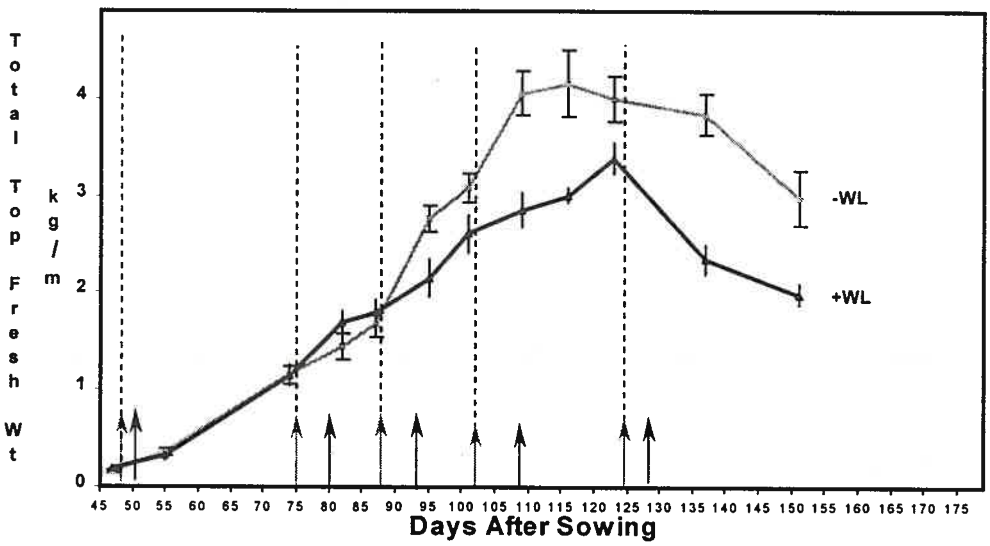

Figure 2. Total top fresh weight over the season, waterlogging experiment 1999/00.

The effect of ridge height on seed cotton yield and total boll number is shown in Fig 3. Yield and total bolls were lowest in the low ridge waterlogged treatment, but there was no significant difference among the high ridge waterlogged, the high ridge non-waterlogged and the low ridge non-waterlogged plots. This result suggested that low ridges were not different from the high ridges under non-waterlogged conditions, but caused a higher susceptibility to waterlogging; with yield and total number of bolls being significant lower in the low ridge waterlogged treatment.

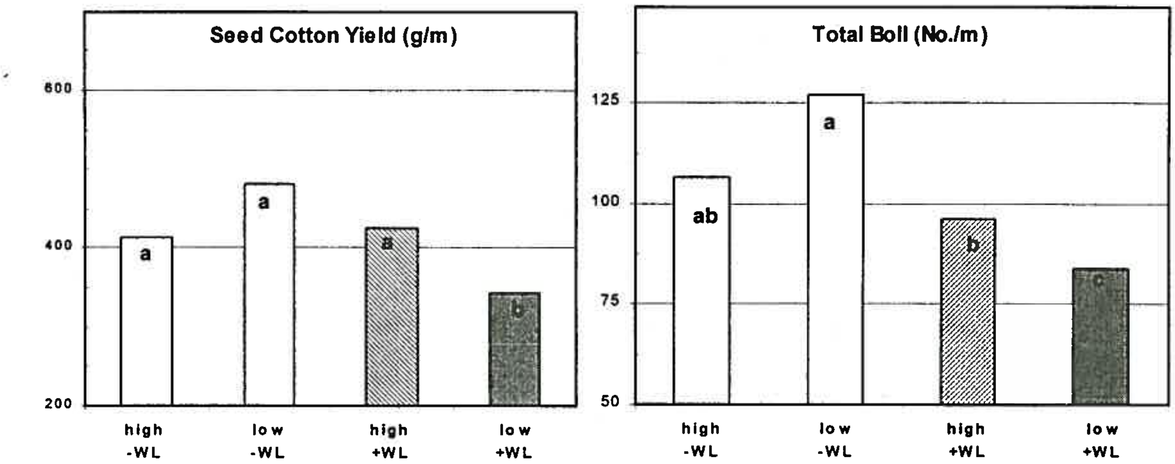

Figure 3. Seed cotton yield and total bolls, Waterlogging experiment 1999/00. Means with different letters are significantly different at 5% probability.

Conclusion

The primary aim of this experiment was to provide information for models on the mechanisms involved in the response of cotton to waterlogging. Nutrient uptake, photosynthesis and crop growth rate will be related to the observed differences in soil oxygen and water content.

In terms of management, it demonstrates the importance of ensuring adequate bed height and the ability to remove excess water from the field quickly, and not later than 48 hrs after irrigation. Attempt to improve cotton tolerance to waterlogging is subjected to further research.

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