EXPERIMENTAL PERFORMANCE OF RAISED BEDS IN PREVENTING WATERLOGGING AND DRAINING EXCESS SURFACE WATER

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INTRODUCTION

Waterlogging has long been recognized as a major constraint to crop growth. Waterlogging in the South Western region of Western Australia (WA) is predominantly the result of perched water tables in duplex soils, caused by rainfall in excess to evapotranspiration limited percolation through the subsoil and lateral drainage. Surface drains have often been recommended to alleviate waterlogging however with little success due to poor lateral water movement. The concept of raised beds has been well established in irrigated agriculture (Tisdall and Hodgson, 1990). However, the application of raised beds to dryland agricultural area, notably waterlogged duplex soils has not been investigated. Raised beds provide short drainage pathways and reasonable hydraulic gradients. They improve lateral water movement, resulting in less water logging in the root environment, and increase in evapotranspiration and subsequent biomass accumulation. This paper describes the first-year results of research into raised beds on waterlogged duplex soils in the South West of WA.

METHODS

Four raised bed demonstration sites and one research site (Cranbrook) were established at different locations across the South West . Two treatments, raised beds and control, were imposed on all sites. The raised beds were installed with a bed former after a deep cultivation of the soil as opposed to the control, which only received a shallow cultivation without changing the relief of the soil surface. The Cranbrook site is instrumented to establish the dynamics of soil-water, which provides information on the various components of the water balance.

The monitoring regime in Cranbrook is described as follows. The soil moisture changes were obtained with a TDR (Time Domain Reflectometry) instrument. The instrument relates the propagation and dissipation of electromagnetic pulses along a cable and steel pins (probes) to the soil moisture content. The system is fully automated and collects soil moisture information every 15 minutes. To establish the shape and the depth to the perched water table from the soil surface, an array of observation wells is installed perpendicular to the interceptor drains. Five wells are installed in every block and readings are taken manually at regular time intervals. Interceptor drains intercept the overlandflow as well as the interflow from the blocks. The flow in the drains is measured with 'V' notch weirs, located at the block boundaries and the water height across the weirs is measured using automated water level recorders. Space limitations in the field enforced the layout of the drain in such way that the flow from the blocks cumulate in the direction of the flow. The flow from the individual blocks is therefore obtained by subtracting the inflow of the drain-section draining a particular block from the outflow of that section.

SOIL MOISTURE DYNAMICS

The soil moisture changes are obtained in various positions and depths of the raised beds and the control. The following diagram (Fig. 1) illustrates the position of the respective probes. Due to the dramatic changes in soil bulk density on the duplex soil, soil moisture changes in the treatments have been converted to degrees of saturation. These have been depicted in Figure 2a and 2b.

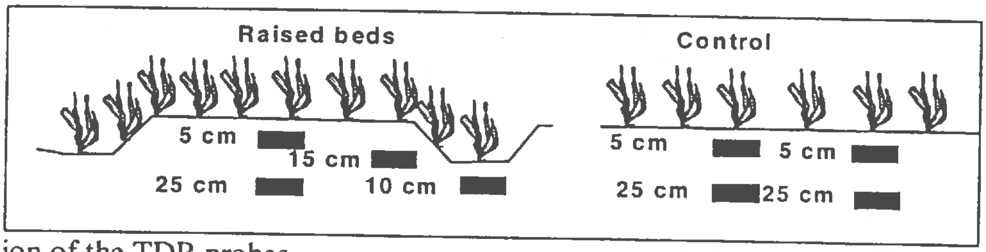

Figure 1. Position of the TDR probes

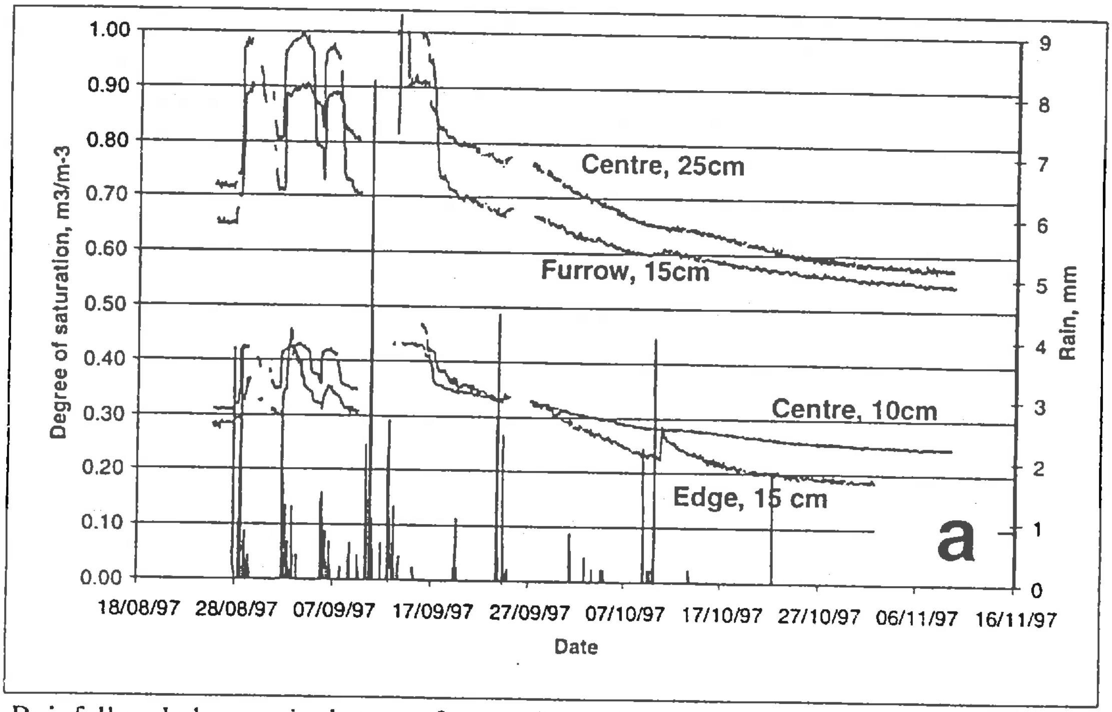

Figure 2a. Rainfall and changes in degree of saturation at different depths and positions of a raised bed.

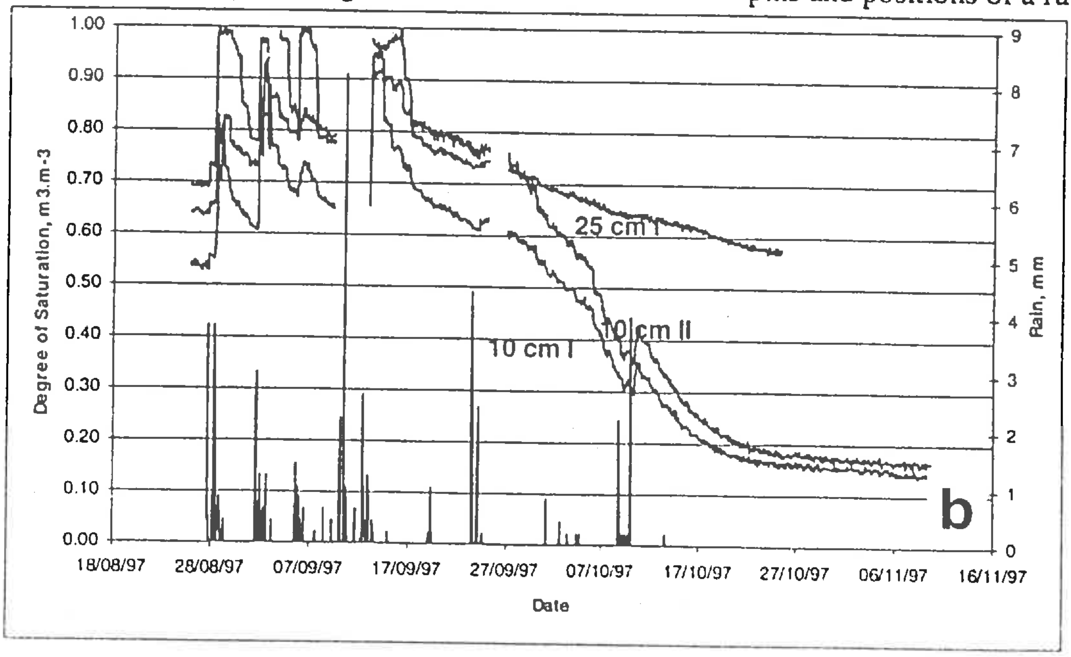

Figure 2b. Rainfall and changes in degree of saturation at different depths and positions of the control.

The centre of the raised bed (Fig. 2a) did not reach saturation at any time during the period of observations whilst during the same period the top 10 cm of the control remained saturated or close to it.

Of interest is the rapid decrease and the low soil moisture content in the edge of the bed. The soil at that depth has a maximum water holding capacity of 0.26 m^3/m^3, 56% gravel and a low clay content and close to the edge, and is therefore able to store only very little water between field capacity and wilting point. It should also be noticed that a rapid decrease in the moisture content occurs at a depth of 25 cm in the raised bed as well as in the control, several days after the rainfall ceased. This decrease (5 mm/day) occurs too fast to be caused by moisture extraction by the roots and should be contributed to internal drainage, resulting in deep percolation or interflow (seepage).

The total soil moisture extraction in the raised beds in the top 30 cm between 17/09 and 27/10 equated to 37 mm and 33 mm in the control. If the total rainfall (11 mm) over that period is included a total of 48 and 44 mm has been evapotranspirated through the crop and the soil which is not unreasonable for a post-flowering period. During that period the raised beds increased 5.94 t/ha in biomass while the control increased only 4.47 t/ha, resulting in the raised beds using the soil moisture more efficiently, 123 kg/mm and 104 kg/mm for the raised beds and the control, respectively. It should be realised that the observation depths have been limited to the top 30 cm due to limited number of probes. To establish the water extraction patterns as well as the total soil moisture extracted by the crop, the observation period has to be extended to cover the entire growing period and the number of observation depths increased.

CONDITION OF WATER LOGGING

The degree of waterlogging has also been established using the manually monitored dipwells. From the observations, the shape of the perched water table has been established. This was clearly affected by the presence of the interceptor drain. Figure 3, illustrates this point through the presentation of the mean depth to the perched water table of 8 plots on three different days.

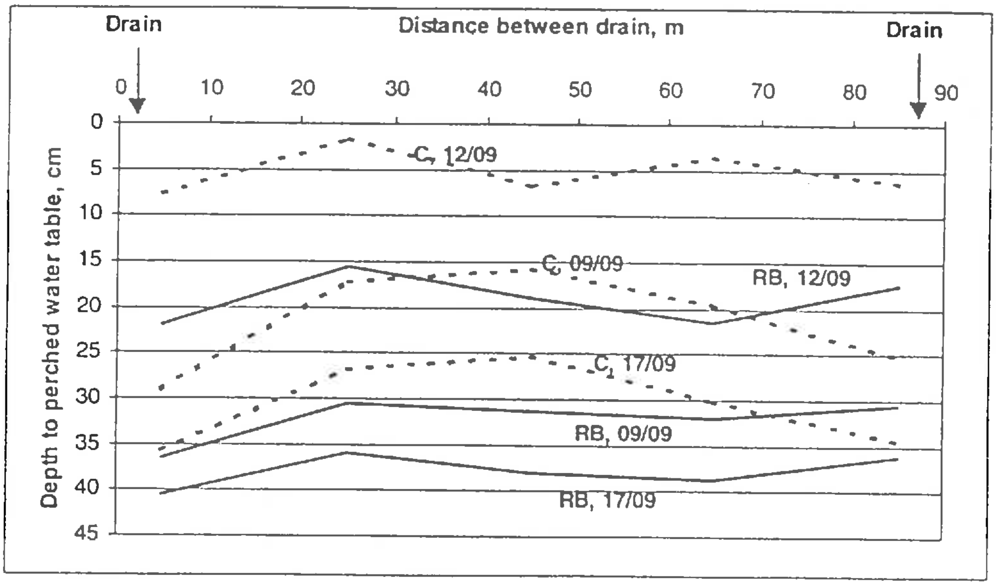

Figure 3. Shape of the perched water table at different days. Before (09/09), during (12/09) and after a rainfall event (17/09).

Before the rainfall event during which 15 mm fell, 09/09, during the event (12/09) and 7 days after the event (17/09). In the control, the water table was close to the soil surface during the event, while in the raised beds the water table remained parallel to the soil surface with some evidence of the effect of the drain on the shape of the water table. The average depth of the water table in the raised beds is 20 cm while the depth of the furrow in the raised beds is 20 – 25 cm. It can therefore be expected that the centre of the beds experience a water table which was temporarely above the level of the furrows, which is explained using conventional drainage theory. Even though the effect of drain on the perched water table is clearly illustrated, the extent of waterlogging was such, even the vicinity of the drain, that the crop was severely affected.

The frequency distribution of the number of observations for a given depth (Fig. 4) indicates that the number of observations at which the depth to the water table was between 0 – 10 cm in the control exceeded the number of observations in the raised beds. While a water table between 11 – 20 cm occurred more frequently in the raised beds than in the control.

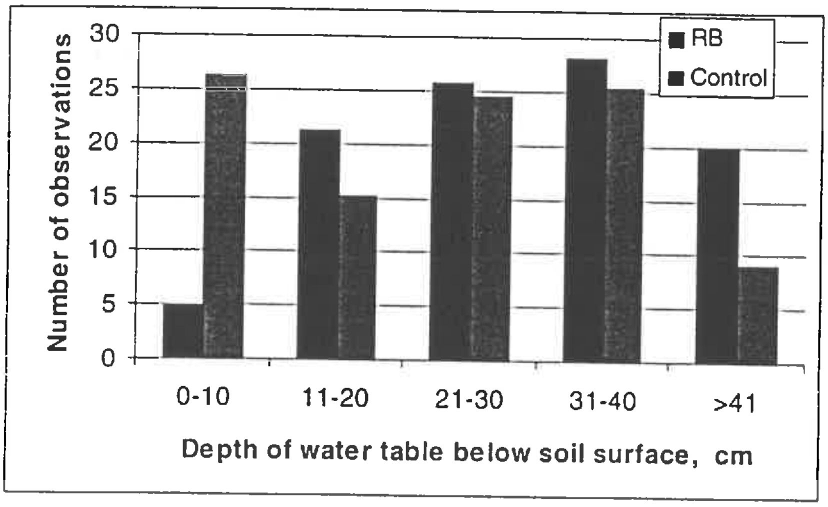

Figure 4 Frequency distribution of the number of observation for a given depth to the perched water table.

RUNOFF DYNAMICS

The runoff from the plots has been measured during the latter part of the winter period. The runoff from the raised beds was usually larger than from the control. This is depicted in Fig. 5.

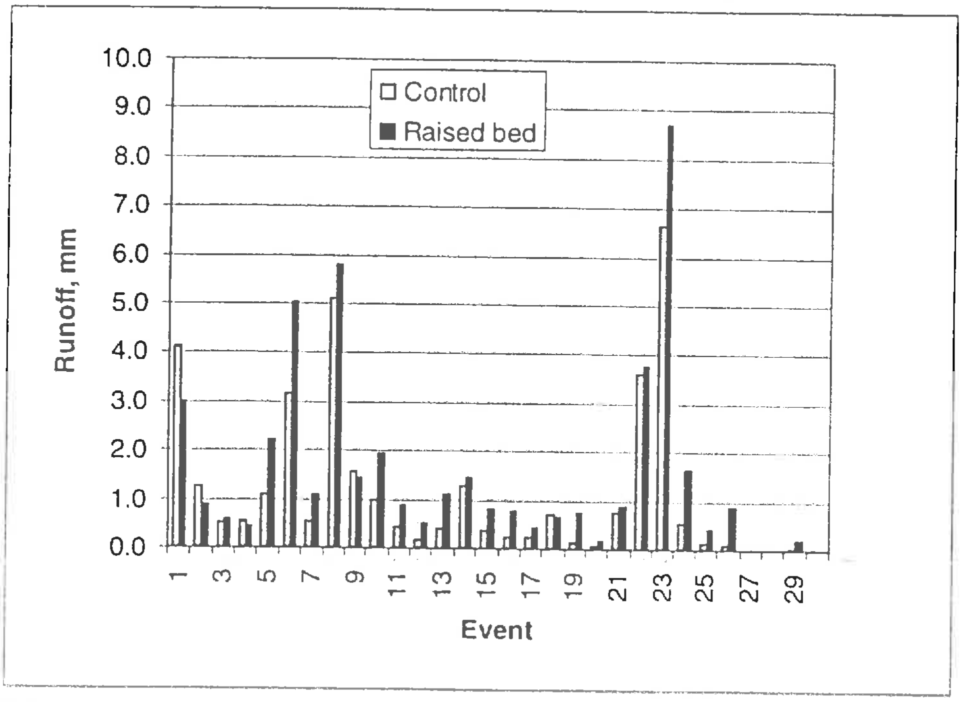

Figure 5. Runoff from the control and the raised bed following various rainfall events.

It was found that on average 25% of the rain disappeared from the control plots and 33% from the raised beds in the form of run off and seepage. These figures from the control correspond with data presented by Cox (1988) for interceptor drains in Mount Barker on a similar soil type.

The differences in runoff behaviour (i.e. time of concentration) has to be distilled from the runoff hydrographs from the individual plots. The incremental method of measuring the runoff increases the complexity of the data analysis. A typical pattern of the runoff is presented in Figure 6.

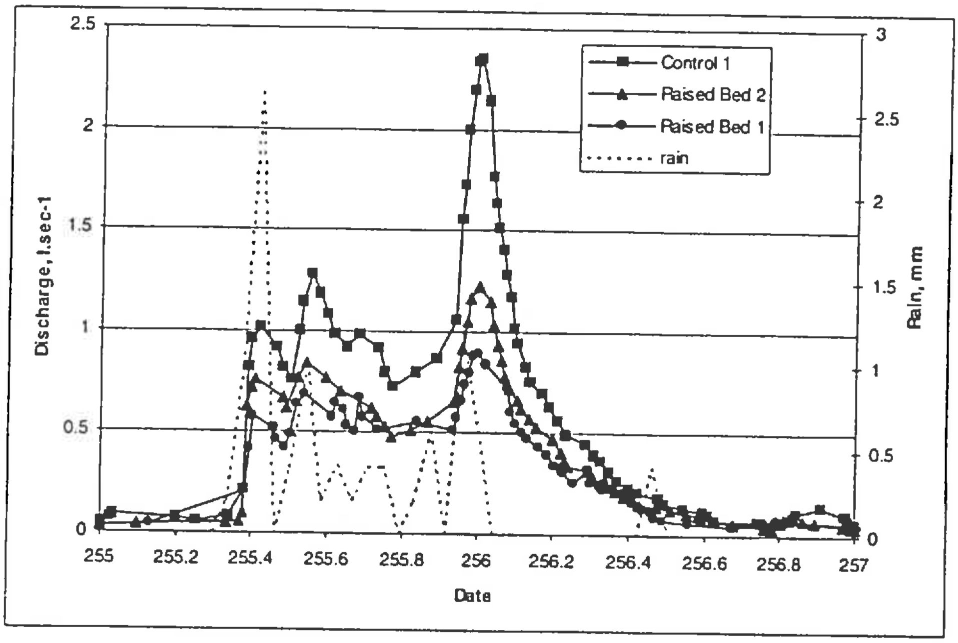

Figure 6. Rainfall and runoff behaviour (discharge over the weir, l/sec) of raised beds and control plots.

There is a delay between the peaks measured from RB1, RB2 and Control1, which is due to the distance between observation points of RB1, RB2 and Control1 (the flow is in the direction: RB>RB2>C1). All three plots show a very rapid rise following rainfall. From the initial data analysis it does not appear that the raised beds behave differently from the control apart from the magnitude of the runoff, but we are still in the process of a more thorough analysis of the data using HYDSYS, a hydrological data analysis package.

CONCLUSION

From the TDR observations it is concluded that the raised beds remain unsaturated in the top 10 cm of the centre of the beds while the control experienced extended periods of water logging during the same period. Equal amounts of soil moisture were depleted between 17/09 and 27/10 but the dry matter increase from the raised beds was substantially higher over that period, indicating that the crop in the raised beds was able to utilize soil moisture more efficiently.

Observations of the perched water table indicated the lower water table in raised beds, during August and September. Given the positive correlation between yield and average depth to the water table (Bakker and Hamilton, 1998), it can be concluded that raised beds can play a major role in the South West of WA in achieving maximum yields on waterlog-prone land.

From the observations of the weirs, it was found that the raised beds had a higher percentage rainfall runoff (33%) than the control (25%). The yield in the raised beds was substantially higher (2.76T/ha) than the control (2.26 T/ha) (Bakker and Hamilton, 1998), it can therefore be concluded that the raised beds made more efficient use of the soil moisture than the control. Provided the evapotranspiration term has been similar for both treatments, it can be concluded from the above that the closing term in the water balance, the deep drainage, has been higher in the control. Apart from an increase in yield, the use of raised beds will have therefore also a beneficial impact on the reduction of the recharge of the ground water system.

ACKNOWLEDGEMENT

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