Raised Bed Farming of Waterlogged Duplex Soils in Western Australia

D. M. Bakker[1], G. J. Hamilton[2], D. Houlbrooke[1] and C. Spann[3]

Agriculture Western Australia.: Albany[1],: Perth[2],: Mount Barker[3].

ABSTRACT

Waterlogging of duplex soils in the Western Australia has long been recognised as a major constraint to the production of agricultural crops and pastures. The work described in this paper is based on the application of permanent raised beds to waterlogged land. Nine experimental sites varying in size from 6 ha to 60 ha have been installed over the last three years. The results indicate improvements in soil structure in the beds are substantial and lasting. Waterlogging is prevented and runoff in wet seasons and during large rain events is increased. The raised beds consistently increased dry matter production and yield for a variety of crops (oats, wheat, barley, canola and field peas) across a range of climatic conditions and soil types. The adoption by farmers of this new soil management system is very encouraging. After only two years of results more than 6000 ha of crop have been grown on permanent raised beds.

KEY WORDS

Raised beds, waterlogging, duplex soils, broad-acre farming.

INTRODUCTION

Waterlogging has long been recognised as a major constraint to crop growth in the South West of Western Australia (WA). Waterlogging is a result from seasonally perched water tables in duplex soils, which are caused by winter rainfall exceeding evapotranspiration and the storage capacity and drainage rates of the soils. Surface drains installed to alleviate waterlogging have little success due to poor lateral water movement (1). The concept of raised beds is well established in irrigated agriculture (2). However, the application of raised beds to dryland agriculture, notably waterlogged duplex soils is new. Raised beds provide short drainage pathways and large hydraulic gradients. They improve lateral water movement into drains (furrows), resulting in aeration of the root environment and improved plant growth. This paper presents the results of the first three years of research into raised beds on waterlogged duplex soils in the South West of WA.

METHODS

Five sites were installed in 1997, at Beverley (B), Woodanilling (W), Mt Barker (MB), Cranbrook (CB) and Esperance (ESP), covering a range of soil types and climatic conditions across the South West corner of WA. In 1998 two sites were added: Quairading (Q) and Lake Toolibin (LT) and in 1999 another two, at Badgebup (BP) and South Stirling (ST). The soil types range from sand and gravel over clay to a sandy clay loam over grey clay. The size of these experimental areas varies from 6 ha (Q) to 60 ha (ST). Two replicated treatments were installed at all sites: the “district” no-till practice, being the Control, and the Raised Bed no-till treatment. The Raised Bed treatment received an initial deep cultivation, the application of gypsum on those sites where dispersible subsoil was present (B, W, Q, LT, BP and ST), the formation of the beds and no-till seeding.

The beds were formed using a bed former, an implement commonly used in irrigated agriculture. Seeding was done with a no-till triple disc seeder. The first five sites (1997) were sown to oats that has a vigorous root system and would aid the establishment of a stable soil structure in the beds. This was followed in 1998 with canola and in 1999 by field peas or wheat. The new sites in 1998 (Q, LT) were sown to oats and barley, followed by canola (LT) and a 'forced' fallow (Q) due to an inability to access the site because of an early break of the season. The new sites in 1999, BP and ST, were sown to canola and wheat respectively because these crops matched the paddock rotation of the farmers.

Changes in the 0-30 cm profile soil-water content over time were collected at CB using a Time Domain Reflectometer (3) whilst perched water tables were monitored with shallow observation wells. At the same site runoff was measured using surface drains to intercept overland-flow and inter-flow from the plots and 'V' notch weirs and capacitance probe water level recorders. In 1998 runoff measuring was extended to the MB and ESP sites. On all sites grain yield and dry matter production data were obtained. Separate dry matter samples were taken from the furrows and the beds.

RESULTS AND DISCUSSION

The soil moisture changes in the surface 30 cm depth of soil were monitored at various depths in the Raised Beds and the Control. Because of large differences in bulk density in the duplex soil profile, soil moisture changes in the 0-30 cm layer were converted to changes in degree of saturation. Typical examples of these changes for each treatment are presented in Figure 1a and 1b.

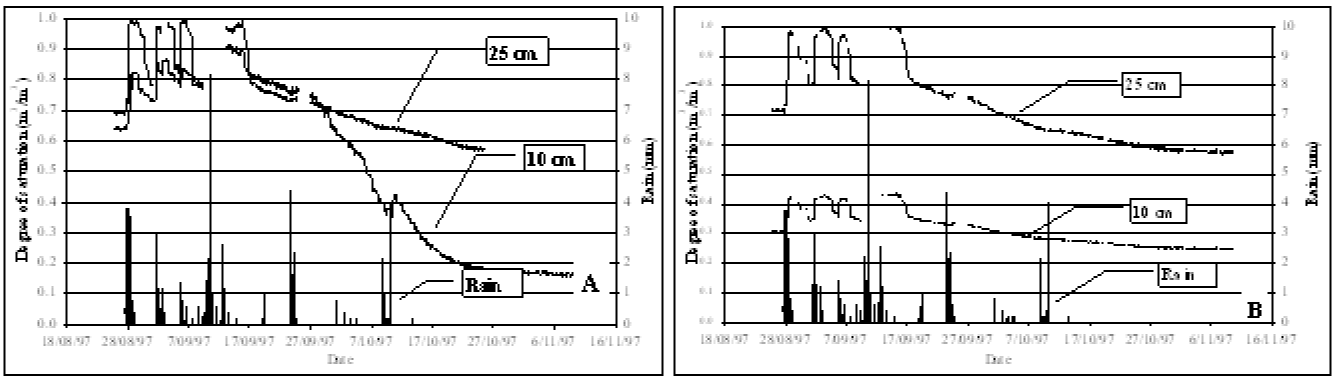

Figure 1. Changes in degree of saturation at different depths of the soil profile of the Control (A) and the Raised Bed (B) as well as the rain that was received at the Cranbrook site in 1997.

These figures show the 10 cm depths of the Raised Beds never exceeded 0.43 saturation, whereas at a depth of 10 cm the Control was frequently saturated and averaged about 0.80 saturation throughout the August -September period which is two to three months after seeding. The crop is then at a stage where it is very susceptible to waterlogging.

Observations of the depth to the perched water table over the last three years are presented as a cumulative frequency distribution curves in Figure 2a whilst the runoff from various sites is presented in Figure 2b.

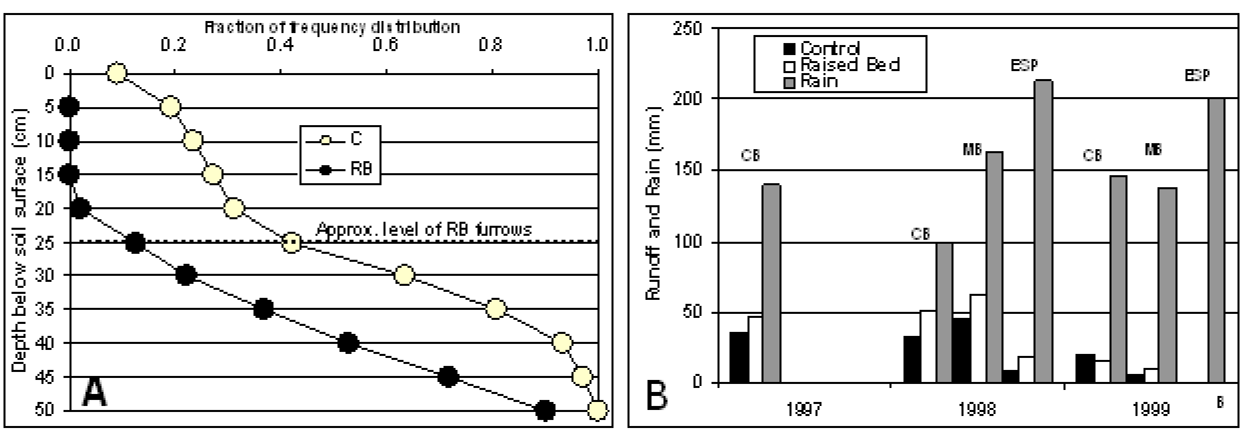

Figure 2. Cumulative frequency distribution of observations for a given depth to the perched water table. C = Control, RB = Raised bed at the Cranbrook site (A) and the percentage runoff and rain from three sites Cranbrook (CB), Mt Barker (MB) and Esperance (ESP) for 1997, 1998 and 1999 (B).

It is shown that the Control has a higher frequency of shallow depths to a perched water table than the Raised Beds, indicating that the beds are very effective in reducing waterlogging. The median (50%) frequency of the depth to the water table in the Control is 20 cm, compared to 30 cm for the Raised Beds. It should be noted that the maximum distance of any of the observation wells in the Control to the nearest surface drain has been 45 m, illustrating the ineffectiveness of drains to alleviate intermittent waterlogging.

Our observations indicated that the Raised Beds produce more runoff than the Control. The runoff from the Raised Beds in Cranbrook (CB) varied from 18 to 50% and from 22 to 32% in the Control. This variation in the runoff from each treatment is caused by a difference in the distribution of the runoff producing rainfall. In 1997 and 1998 most of the rain fell in July and August when there was an incomplete coverage of crop canopy. In 1999, the winter rains came in smaller amounts but more frequently. One major rainfall occurred in 1999 towards the end of September but by then there was a substantial crop cover and a drying profile. No runoff occurred during the growing season of 1999 in Esperance. The results indicated that Raised Beds are likely to shed more runoff than the Control seedbed in moist conditions. However, in periods of less than average rain, the drier Raised Beds are likely to shed less runoff because of their drier conditions and greater infiltration capacity.

Productivity

Some trends in the growth of crops on the Raised Beds and the Control are presented in Figure 3.

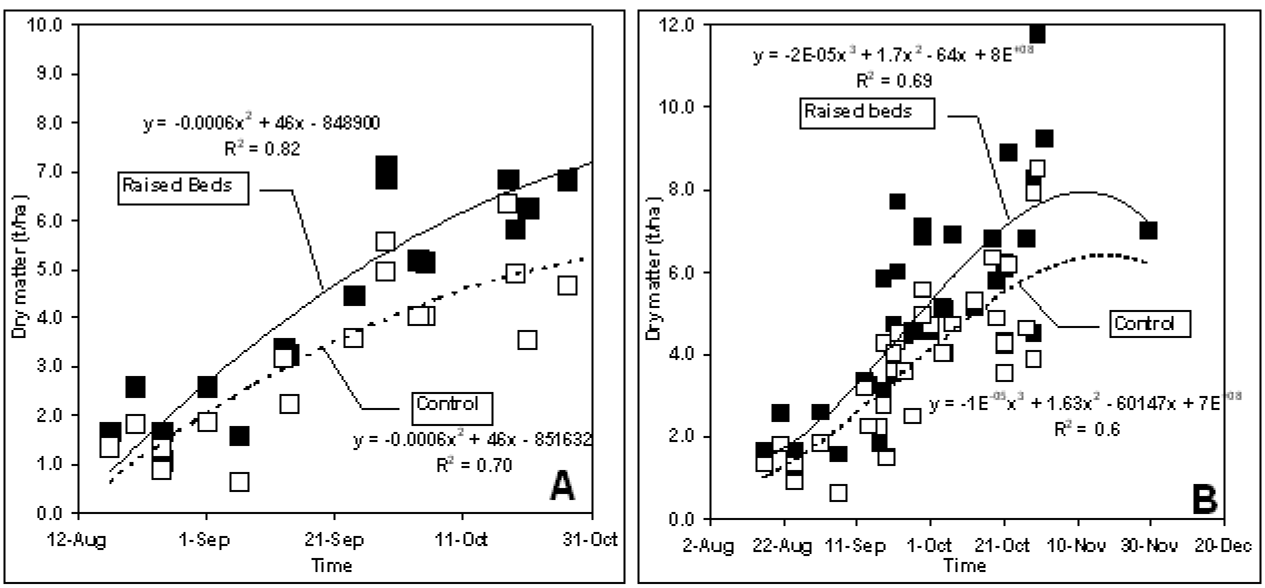

Figure 3. Dry matter accumulation of the Raised Beds (beds only) and the Control of all sites during the 1999 season (A) and for all the three years (B).

The Control and the Raised Bed treatments produced some good correlations of time vs. dry matter production considering the geographical distribution of the sites. The production function of the Control is lower than the Raised Beds, indicating the production on the Control occurs under more stress than on the Raised Beds. When the relationships are extended to include the three year results, the correlations have smaller but still reasonable correlation coefficients. The productivity of the Raised Beds area is affected by the very poor productivity of the furrows. Including those results which was only done for the

1999 data and calculating the total productivity of the raised bed area on the basis of 71% beds and 29% furrows, little difference was found between the Control and Raised Bed productivity curve. This was however not reflected in the yield as presented in Table 1.

Table 1. Yields for the 1997, 1998 and the 1999 growing seasons. Loc. = Location, RB = Raised beds, C = Control, P = P-value of the ANOVA, % = Percentage difference compared to the Control, Bar = Barley, Wh = Wheat, Can = Canola, FP = Field Peas.

?	?	**1997**	?	?	?	?	?	**1998**	**?**	?	?	?	?	**1999**	?	?	?
Loc.	**Crop**	**RB, t/ha**	**C, t/ha**	**P**	**%**	**Loc**	**Crop**	**RB, t/ha**	**C, t/ha**	**P**	**%**	**Loc**	**Crop**	**RB, t/ha**	**C, t/ha**	**P**	**%**
B	*Oats*	1.44	1.14	0.57	17	**W**	*Can*	0.91	0.69	0.006	32	**B**	*FP*	1.96	1.39	0.03	41
W	*Oats*	2.50	1.70	0.03	47	**CB**	*Can*	1.62	1.22	0.003	33	**W**	*FP*	1.47	1.03	0.21	43
CB	*Oats*	2.76	2.26	0.06	22	**MB**	*Wh*	2.05	1.88	0.710	9	**CB**	*Wh*	2.41	1.88	0.40	28
ESP	*Oats*	2.58	1.78	0.20	45	**ESP**	*Can*	2.20	2.17	0.801	1	**MB**	*Can*	2.15	1.90	0.13	13
												ST	*Wh*	3.50	2.95	?	18
?	?		?	?	?							**ESP**	*Wh*	3.64	2.71	0.10	34
Mean					**33**	**?**	***?***			**?**	**19**						**31**
MB*	*Oats*	2.00	2.59	0.30	-23	**Q***	*Bar*	2.27	2.11	0.63	8	**LT***	*Can*	1.34	1.18	0.14	14
?	?		?	?		**B***	*Can*	0.94	0.98	0.75	-4	**BP***	*Can*	1.75	1.82	0.61	-4
?	?		?	?	?	**LT***	*Oats*	2.24	2.0	0.17	7	?	?	?	?	?	

									9		
?	**RB**	**C**	**%**	**P**	?						?
Mean	2.23	1.76	26	0.09	?	?	?	?	?	?	?
Mean*	2.08	1.77	17								

: These sites experienced agronomical problems unrelated to the Raised Beds. Mean: Mean including the sites that experienced a problem

Over the three years of experimentation, one site suffered from a yield recording problem, others from an excessive seeding depth, insect damage or the lack of fungicide on some Raised Bed replicates. These sites have been marked with a star and deleted from the main analysis of the yield data. The yield from the Raised Beds was consistently higher compared to the Control. The mean yield of all three years of the Control was 1.76 t/ha vs. 2.23 t/ha from the Raised Beds which is a significant average increase of 26% (P=0.09). This difference was reduced to 17% when the sites that suffered some problems were included.

CONCLUSION

It has been demonstrated that raised beds have a positive impact on the prevention of waterlogging and crop productivity under waterlogged conditions. The positive results of these trials and the experience of one farmer at Kondingup (SE WA) with raised beds, resulted in a rapid adoption of raised bed systems among farmers in that region of WA. Only after three years of experimental work, farmers in the region had already planted 6000 ha with crops using raised beds.

ACKNOWLEDGEMENTS

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