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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Preface

This document presents the results of the second year of a 5-year research and development project to develop management practices and cropping systems to prevent waterlogging and increase the productivity of waterlogged lands.

The results presented in this report reflect the large range of soil, water, crop and climate observations carried out to assess the impact of the various treatments. The main points of these observations have been highlighted and discussed in view of the performance of the treatments.

The number of sites was increased from 5 in 1997 to 7 in 1998 while several sites: Cranbrook, Mount Barker and Esperance were enlarged. The two new sites: Quairading and Toolibin were installed on different types of soil and topography.

The size of the experimental sites ranges from 6 ha in Quairading being the smallest in size and to Toolibin the largest (60 ha). This type of field experimentation using "paddock" scale sites can not be undertaken without the help of collaborating farmers. Besides, Harvey Morrell, Russell Thomson and Mark and Clem Addis who collaborated in 1997, Tim Shenton and Lachlan White have kindly allocated land and facilitated seeding and harvesting in 1998. In addition, we have again received good support from the Mount Barker (MBRS) and Esperance Downs Research (EDRS) Service Unit staff.

The data presented in this report are treated separately for every site as well as in the form of a aggregated summary. The effects of the weather and the soil conditions on yield and overall performance of the raised beds is discussed for the various sites individually.

Through this report the authors hope that the readers will develop a sense of enthusiasm for the concept of raised beds in the never ending quest to increase the productivity of arable agriculture.

Derk Bakker, September 1999

Contents

Introduction

Background

- Surface drains do not, by themselves, alleviate waterlogging in soils with little or no macro porosity. They remove excess surface water and a limited amount of lateral sub-surface seepage. Water loss from soils with small pores is dominated by evaporation, and in winter this is exceeded by rainfall from May through to August over the western and southern areas of the WA region.
- No-tillage crop establishment improves root retention and leads to improved water transmission and aeration properties and productivity.
- Raised beds in irrigation areas are used to get water on to the paddock and in to the soil.
- Our approach is to combine raised beds with no-tillage crop establishment practices to get water out of the soil and off the paddock – the reverse of the irrigation use of beds – and drain and aerate soils
- Also, we will use the experience of eastern states irrigation farmers and machinery companies, who combine to grow broad-acre crops, such as lupins, canola, barley etc., on raised beds with adapted but essentially conventional seeders and harvesters to minimise the investment in machinery required to adopt raised bed cropping.

Project aims

- To map the distribution of waterlogging occurrences relative to soil type and climate
- To develop soil, water and crop management practices to alleviate or prevent waterlogging
- To establish the economics of effective treatments, relative to geographic location and waterlogging frequency.

Rationale

i. We intend to use simulation modelling to illustrate how waterlogging varies geographically, to provide farmers with information that will aid their choice of the most cost-effective control treatment for their circumstances.
ii. In locations where rainfall exceeds pan evaporation, soil evaporation is controlled by the evaporative power of the atmosphere, not the soils' ability to supply water to the atmosphere. Macropores need to be created and retained by minimal tillage practices and combined with a form of drainage that removes both excess surface and internal soil-water and thus rapidly drain and aerate the root zone of crops.
iii. Specification of dimensions and conditions for raised beds
    - Plant physiological studies of waterlogging indicate that soils need to have at least ≈ 8% air-filled pore space for plants not to suffer waterlogging (anaerobic) stress. Thus*, the first essential specification* to prevent waterlogging is that soils need at least 8% of their volume to drain and aerate within 24- 36 hours.

- Drainage calculations show that soils in good conditions can have beds up to 4m wide and still drain a perched water table in about 36 hours. Thus *the second essential specification* of soil conditions is that the saturated hydraulic conductivity of the root zone needs to be about 50 mm/hr.

- For soils with good root zone conditions *spacing between drains can be determined by practical considerations*, such as the width of a tractor's wheel span. The most common type used is a front-wheel assist 150 HP tractor. This creates furrows which are 1.83m (or 6ft) apart (centre – centre) and as wide as their tyres, i.e. 0.45m (or 18") wide. Beds formed between these tracks are thus ≈1.4m wide across their top.

iv. Paddock-scale research & development
One detailed research site and six demonstration trails have been installed. These are all effectively "paddock-scale" ranging in area from 6ha to 60ha. All are seeded, sprayed and harvested with conventional farm machinery.

v. The research site
The research site is located at Cranbrook, on what was Clem Addis property, "Gordon River Estate", presently owned by the Armstrong family.

The hypotheses being tested at Cranbrook are:

- that the macroporosity necessary for rapid drainage and aeration can be created by no-tillage crop establishment practices imposed in a controlled traffic regime:
- that the rapid drainage required of water-filled macro-pores will be best achieved in a system of raised beds;
- that a continuous crop rotation of oats, canola, cereal, legume (e.g. lupins, faba beans, chickpea) will be sustainable in terms of weed and disease control

The treatments imposed are as follows:

a) Raised beds with no-tillage crop establishment *with* summer grazing
b) Raised beds with no-tillage crop establishment *without* summer grazing
c) Control with no-tillage crop establishment *with* summer grazing
d) Control with no-tillage crop establishment *without* summer grazing

Each treatment has four replicates

Other questions to be addressed by this research are:

- What changes are made by functioning raised beds to runoff and deep drainage?
- What quantities of runoff and soil-water drainage are potentially conservable from areas of raised beds?
- What is the capacity for raised beds to rehabilitate moderately saline soils and reduce off-site transport of phosphorus?.

In addition, a comparison is made between raised beds of different ages (ie. 1, 2 and 3 years) and runoff behaviour. The newly formed beds have been installed in what used to be a non-productive part of the paddock in the vicinity of the 'W' drain. These beds are also twice as long as the original ones.

vi. Demonstration trials

The treatments applied to the Paddock-scale demonstrations are:

- Best-bet (i.e. raised beds with no-till crop establishment +/- gypsum, if required.
- Normal practice (i.e. control area with no-till crop establishment)

Four sites were installed in 1997 which were located on:

- Harvey Morrell's property, "Glenferrie" at East Beverley;
- Russel Thomson's property, "Kunmallup" at Woodanilling;
- MtBarker Research Station Manurup Annex;
- Esperance Downs Research Station.

In 1998, two additional sites were included in the program. These are located on:

- Tim Shenton's property, "Nuytsia" at Quairading;
- Lachlan White's property, "Nepowie" at Lake Toolibin;

Each treatment has three or four replicates.

vii. Acknowledgements

Grateful acknowledgement is made of financial, technical and machinery support provided by:

GRDC Western Region Panel
Gessner Industries, Toowoomba, Qld
Walker's, Merridin
Simplicity Airseeders, Dalby, Qld
Geoff Perkins Machinery, Narrogin
Tim Shenton, Quairading
Harvey Morrell, East Beverley
Lochlan White, Lake Toolibin
Russell Thomson, Woodanilling
Clem and Mark Addis, Cranbrook
and staff of the MBRS and the EDRS.

2. Demonstration Trial "NUYTSIA"

Tim & Cheryl Shenton, Quairading

Paddock history

The paddock is located in the valley floor which is severely affected by salinity. The productivity has been very poor due to frequent waterlogging during the winter months in conjunction with high salinity.

Prior to the installation of the raised bed demonstration trial the paddock had a barley crop which did not yield well.

Site lay-out

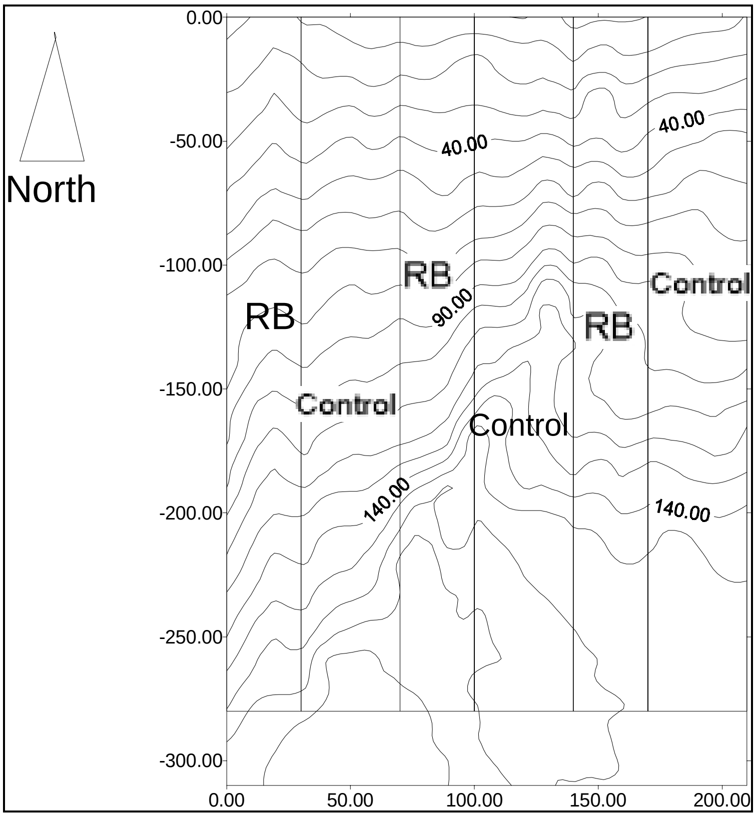

Figure 2.1 Site lay-out, 6 ha.

Operations

1 April	Soil sampling for EC and gypsum requirement
11 May	Ripping
12 May	Mounding
4 June	Seeded, Barley 50 kg/ha, Agras & Trace 120 kg/ha
21 July	Soil sampling for salinity
21 July	Aerial application urea, 50kg/ha
14 Sept	Soil sampling for salinity
20 Nov	Harvest
01 Dec	Soil sampling for salinity

Results

As can be seen from Table 2.1 the salinity profile in the control changed substantially from April to the end of July, with little accumulation over the winter months and an increase from September to December. In the raised beds, the salinity levels in the top 20 cm were changed dramatically from April to July, decreased over the winter months and increased again during spring and early summer.

Table 2.1 Salinity profiles, mS/cm (1:5) Average of 12 samples, Stdev and Coefficient of Variation (%) between brackets.

Location		April	21 July	14 Sept	Difference	1 Dec	Difference
Control	0-10cm	359 (343, 95%)	26.0 (19, 73%)	24 (23, 96%)	-1.8	20 (11, 55%)	-4.4
Control	10-20cm	83 (53, 63%)	36 (14, 39%)	30 (20, 66%)	-6.6	84 (56, 67%)	54.6
RB	0-10cm	359 (343, 95%)	122 (64, 52%)	64 (36, 56%)	-58.0	108 (59, 55%)	*44.0*
RB	10-20cm	83 (53, 63%)	76 (25, 33%)	81 (34, 42%)	4.9	149 (147, 99%)	*68.6*

Table 2.2 Rainfall, actual with decile ranking* between brackets and median.**

	April	May	June	July	Aug	Sept	Oct	Nov	Total April-Nov
Actual, mm (decile ranking)	37 (8)	13 (2)	97 (8)	55 (5)	57 (8)	25 (5)	5.5 (2)	12 (6)	301.5
Median, mm	14	50	67	57	47	26	16	10	287

*: decile ranking = Decile ranking is the position of the monthly rainfall in a distribution of historical rainfall arranged in order of magnitude, e.g. Decile 2 rank means the recording is in the 10% to 20% range, i.e. low end of the scale.
**: median = a measure of central tendency. The observations are arranged in order of magnitude and the middle value is the median

In June (Table 2.2) 97mm rainfall fell on the trial site. Given the compacted nature of the sub soil and the shallow top soil, it is very likely that the top soil in the control reached saturated conditions rapidly, dissolved and flushed out the salt. During the installation of the raised beds, the salt was mixed throughout the top 20 cm of the profile. During the rainfall events in June saturation was not achieved in the raised beds which could therefore not be leached to the same extent as the control. Having started at higher salinity levels in July in the raised beds compared to the control, it is evident that more salt was removed in the raised beds during the winter months than in the control.

In spring and early summer the crop water use is predominantly driven by plant root extraction from the root zone. The continuous upward movement of soil moisture, driven by root uptake and the capillary action with very little leaching due to little rainfall resulted in an increase in the salt levels in the top 20 cm in both the control and the raised beds.

The large (spatial) variability in the salinity data (CV>90%) and the very limited number of observations make it difficult to make conclusive statements about the salinity dynamics of raised beds. Further research to investigate this is required.

Table 2.3 Yield data, t/ha

Plot	**C**	**RB**
1	2.46	2.21
2	2.37	2.46
3	1.51	2.14
Mean	**2.11**	**2.27 (+7.5%)**
Stdev	*0.52*	*0.17*
CV, %	*25*	*8*
P[#]	*0.634*	

#: P = Indicate probability level that means are equal.
To make treatment means significantly different for agricultural purposes P<0.05.

Due to seeding difficulties on the raised beds (too deep), the crop development on the raised beds was delayed. Despite this and the higher salt levels in the raised beds, the beds produced a larger crop. The better aeration status in the beds (determined for other sites) eliminated the interaction between waterlogging and salinity and enabled the crop on the raised beds to withstand higher levels of salinity than the control.

This site as well as all the others have been harvested with a normal harvester, Figure 2.2. The wide front tyres were replaced by narrower tyres to cater for the width of the furrows.

Figure 2.2 A normal harvester was used at all the sites.

Comments
Despite the higher salinity levels and the greater seeding depth on the raised beds, they did produce a larger barley crop albeit not statistically not significant at a 5% level.

3. Demonstration Trial, "GLENFERRie"

Harvey and Diane Morrell, Beverley

Paddock history

- Paddock 11 has been used mostly for pasture. Its productivity has been constantly poor.
- The paddock suffers prolonged waterlogging during winters with average rainfall.
- On the few occasions it has been cropped (about 6 times in the last 20 years) it has produced an average yield of 0.7 t/ha.
- Prior to the installation of the raised bed demonstration trial in 1997 it was in volunteer pasture.
- In 1997 the paddock was divided up into raised beds and control areas and cropped with oats.

Site lay-out

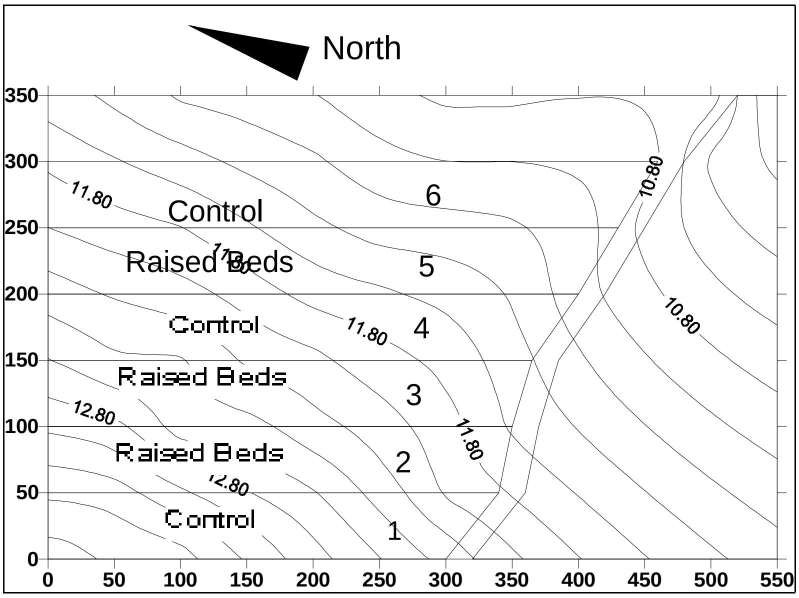

Figure 3.1 Site lay-out of the raised bed trial, 16 ha.

Operations

30 April Furrows and bed shoulders to renovate the damage done by machines with track widths different from required (1.83m or 6ft)
14 May Sprayed Simazine 550gr/ha,
Atrazine 550 gr/ha, Roundup .8l/ha, Insecticide 70ml/ha
Seeded. TT Canola Clancy 5.5 kg/ha + Agrich 65 kg/ha
15 June Reseeded, Raised beds only at 3 kg/ha
27 July Sprayed Sertin Plus 500 ml/ha, Oil 1%/ha, Insecticide 70ml/ha
28 July Topdress Urea 60kg/ha
21 Sept First biomass cut
21 Oct Second biomass cut
17 Nov Direct harvested

Results

The rainfall summary for the 1998 growing season is presented in Table 3.1

Table 3.1 Actual, decile ranking and median rainfall figures for 1998 for East Beverley automatic weather station (Actual) and Beverley PO (Decile and Median figures).

Month	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Tot, April-Nov
Actual, mm (decile ranking**)**	27.4 (7)	30.8 (3)	83.8 (6)	42.6 (2)	61.8 (6)	36 (5)	11.4 (3)	10.0 (6)	266.4
Median, mm	18	52	78	71	57	34	19	9	338

The last growing season saw a well below average rainfall. Whilst June, August and September received average rainfall, May and July were dry.

Difficulties in seeding the raised beds due to poor depth control led to very low germination numbers on the raised beds and it was decided to resow the raised beds only. This was done one month after seeding the first time. Crop dry matter was sampled twice during the growing season and is presented in Table 3.2.

Table 3.2 Dry matter sampling. (n = 5). Percentage difference between brackets.

	DM1, 21 Sept.		DM2, 21 Oct.	
Plot	C	RB	C	RB
1	4.00	3.78	5.25	3.91
2	3.87	3.26	4.26	4.45
3	3.06	3.56	3.34	4.24
Mean	3.64	3.53(-3%)	4.28	4.20 (-2%)
StDev	0.51	0.26	0.96	0.28
CV, %	14	7	22	6
P	0.75		0.89	

Little difference was found between the treatments. As the season progressed the raised beds improved compared to the control even though Rep 1 of the Control was at all times the most productive. This extended to the yield, see Table 3.3.

Table 3.3 Canola yield, oil content (1 sample/plot) and average number of plants/m2 (5 samples/plot). Percentage difference between brackets.

	Yield, T/ha		Oil content, %		Plants/m2	
Plot	C	RB	C	RB	C	RB
1	1.21	0.95	41.6	42.2	106.2	68.4
2	0.90	0.94	42.4	42.9	127.1	66.2
3	0.82	0.92	42.6	42.5	90.2	55.1
Mean	0.98	0.94 (-4%)	42.2	42.53	107.8	63.26
StDev	0.20	0.01	0.53	0.35	18.50	7.14
CV, %	20	1	1	1	17	11
P	0.75		0.41		0.017	

The mean yield of the raised beds was less than the control but much more across the replicates. Plot 1 of the control was substantially larger than the rest. The oil content in the raised beds was slightly higher. What is clear from Table 3.3 is the larger number of plants in the control. It was found that in many furrows the crop was not established due to shallow sowing, poor establishment and multiple passes of the tractor during top dressing and spraying. This has a much smaller effect on the Control treatment than on the RB due to the lack of controlled traffic in the control and the drier soil conditions of the top soil in the control at the time of trafficking and therefore less disturbance of the crop on the control. It should therefore be noted that similar yields were obtained in raised beds as the control with a smaller number of plants and despite the later (one-month) re-seeding of the raised beds. This reflects the big difference in plant development between the raised beds and the control. Whilst the plants on the control were often thin and flimsy, the plants on the beds were large, robust and generally in a better shape, particularly the root system as will be discussed later.

The beds had been renovated (ie. furrows reshaped without deep cultivation) at the beginning of the season. From Fig. 3.2 it is clear that the large differences introduced in 1997 in the dry bulk density remained at all depths.

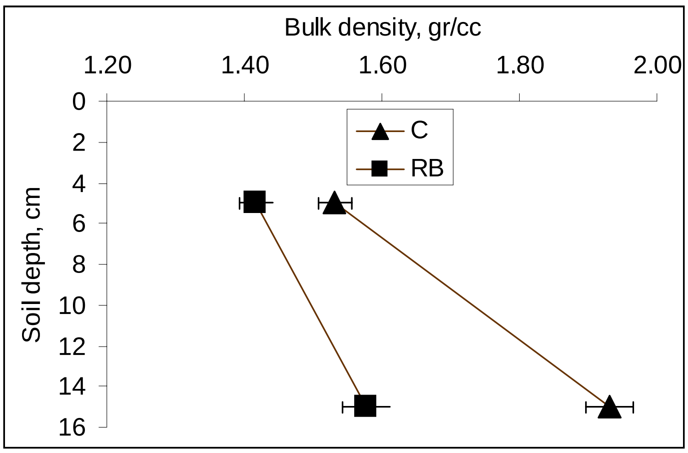

Figure 3.2 Bulk density, gr/cc

The consequence of the lower bulk density in raised beds is the improved root growth. Canola has normally a tap root which can be pruned under conditions of waterlogging or inhibited in growth in the presence of a hard pan. Figure 3.3 illustrates the root development of two plants pulled out of the control and the raised beds. The roots system developed properly in the raised beds while the root system in the control was lumped and restricted due to water logging and a dense, compact soil.

Figure 2.3 Illustrations of two different root systems.

Water logging was assessed by measuring the depth to the water table from the soil surface throughout the growing season. The depth to such perched water tables as a function of time is presented in Figure 3.4.

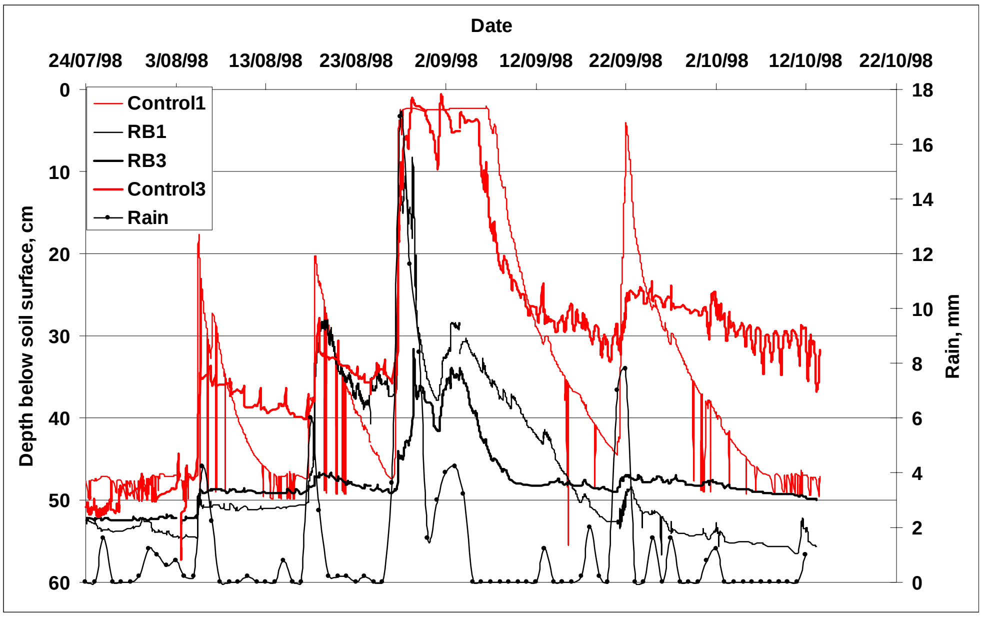

Figure 3.4. Depth to the perched water table as a function of time for 2 dip wells equipped with an automatic water level recorder in the control and the raised beds.

From the figures it can be seen that substantial waterlogging only occurred towards the end of August in the control. At no point in time did waterlogging (ie perched waterlevel < 10cm surface) occur in the raised beds. During the rainfall event at the end of August, the perched water table in the raised bed rose as quickly as in the control but drained rapidly.

Several observations of wilting-tip syndrome were made in the control area. This syndrome is indicative of lack of calcium in the tip of the plant. The calcium is relocated from the tip to other parts of the plant during periods of stress, particularly waterlogging.

Figure 2.4 Wilting-tip syndrome

Comments

Lack of good growing season rainfall did not result in waterlogged conditions in the control area and resulted in small yields in the control as well as the raised beds. Even though the raised beds were seeded one month later and had a much lower plant number, the yields were not statistically different, illustrating the robustness of the raised beds as well as the ability of the canola plant to small compensatory growth in smaller plant populations.

4. Demonstration trial, "Nepowie",

Lachlan White, Lake Toolibin

Paddock history

- This paddock was added as a raised bed trial in 1998.
- Situated in a flood plain and has a history of waterlogging during the winter months.
- Prior to the raised bed trial it was in a pasture/cropping rotation.
- Small undulations are present across the paddock. A sand dome is located in the North part of paddock.
- The soil is a very shallow sand on clay duplex soil. The depth to clay varies across the paddock.

Site lay-out

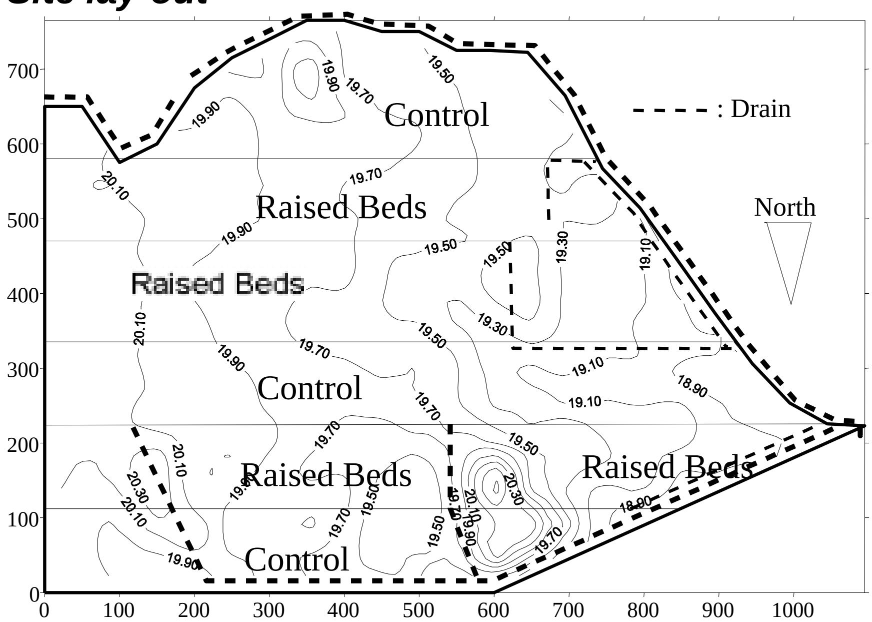

Figure 4.1 Site lay-out of the raised bed trial at Nepowie, 60ha.

This site has been the largest of the seven sites in 1998. It provided challeges in terms of drain layout (dashed lines) and providing optimum drainage of the raised beds. Several cross drains were installed to drain the larger depressions.

Operations

27 April	Sprayed. Roundup & Laise 0.5 L/ha
25 May-1June	Ripped + Mounded
3 June	Seeded Oats Pallinup 70kg/ha + Agras blend 120 kg/ha Only Raised beds
12 June	Seeded Control with air-seeder, Oats Pallinup 70kg/ha+Agras blend 120 kg/ha
17 July	Sprayed Glean 15gr/ha + Oil 0.2 %/ha
23 July	Emergence count
28 July	Top dressing Urea 60 kg/ha
22 Sept	First biomass cut
22 Oct	Second biomass cut
24 Nov	Harvested

Results

The rainfall summary for 1998 was obtained from a grower about 10km South from the trial site. Long term data were taken from Wickepin, 25km North West of the site.

Table 4.1 Rainfall summary, actual and decile ranking and the median.

Month	April	May	June	July	Aug	Sept	Oct	Nov	Total, April_Nov
Actual, mm (Decile ranking)	58 (9)	34.5 (3)	68.5 (6)	46 (3)	87 (9)	17.5 (2)	13.5 (4)	9 (3)	325.2
Median, mm	22	50	69	68	47	37	22	13	329

From the table it is clear that July and September were dry months. Only on one occasion in August (28/08) did the drains run following 58 mm of rain. Without that rain it would have been a very dry year.

The raised beds were sown with the Great Plains seeder while the control was sown with Nepowie's airseeder. Again poor depth control of the seeder on the raised beds resulted in a deep seed placement, delayed emergence, slow canopy closure and an increase in the weed burden, particularly rye grass. However, one month after seeding little difference was found in emergence but with a trend to an increase in plant numbers on the raised beds.

Table 4.2 Establishment plant numbers, pl/m^2

Plot	C	RB
1	97.0	124.8
2	130.5	122.2
3	112.0	138.3
Mean	113.2	128.4
Stdev	*16.8*	*8.7*
CV, %	*15*	*7*
P	*0.23*	

The advantage of the raised beds extended throughout the growing season.

Table 4.3 Dry matter (T/ha) and yield (T/ha) results

	DM1, 22 Sept		DM2, 22 Oct.		Yield, 24 Nov.	
Plot	C	RB	C	RB	C	RB
1	3.70	8.00	6.45	8.62	2.03	2.28
2	4.94	6.88	6.54	9.10	2.21	2.34
3	4.96	7.18	n.a.	n.a.	2.04	2.11
Mean	4.53	7.36 (+62%)	6.49	8.86 (+36%)	2.09	2.24 (+7%)
Stdev	0.72	0.58	0.06	0.34	0.10	0.12
CV, %	16	8	0.9	4	5	5
P	0.006		0.01		0.17	

n.a.: not available

The considerable greater DM production (or growth) crop improvements on the raised beds compared to the control (% difference between brackets) reduced as the season progressed. A similar pattern was found last year in Beverley and Cranbrook which was then attributed to the dry finish to the season. In addition to the effect of the weed burden on the yield of the raised beds, the lack of the good finishing soil moisture in the raised beds to support a large crop might have reduced the yield potential on the raised beds.

Figure 4.2 Control area (left) and the raised beds (right)

Figure 4.3 Cross drains after rainfall, one month after seeding

Comments

Poor seeding depth in the raised beds, weed pressure and generally a non-waterlogged year resulted in reduced differences between the treatments. This site was the largest in 1998. The intensive contour survey of the surface gave the opportunity to address issues of more complicated drainage design (ie. shallow cross drains) and the drainage of remote depressions.

5. Demonstration Trial, "Kunmallup"

Russell & Margaret Thomson, Woodanilling

Paddock history

- The front paddock has been cropped as part of the farm rotation. It has had an average cropping frequency of one crop every three years.
- The lower section of the paddock (where the raised beds trial is located) has been always the least productive due to regular seasonal waterlogging. The average production from this section is about 0.5 t/ha
- In 1996 the paddock was sown to lupins and none was harvested from the lower section.
- Raised beds were installed in 1997 and sown to oats.

Site lay-out

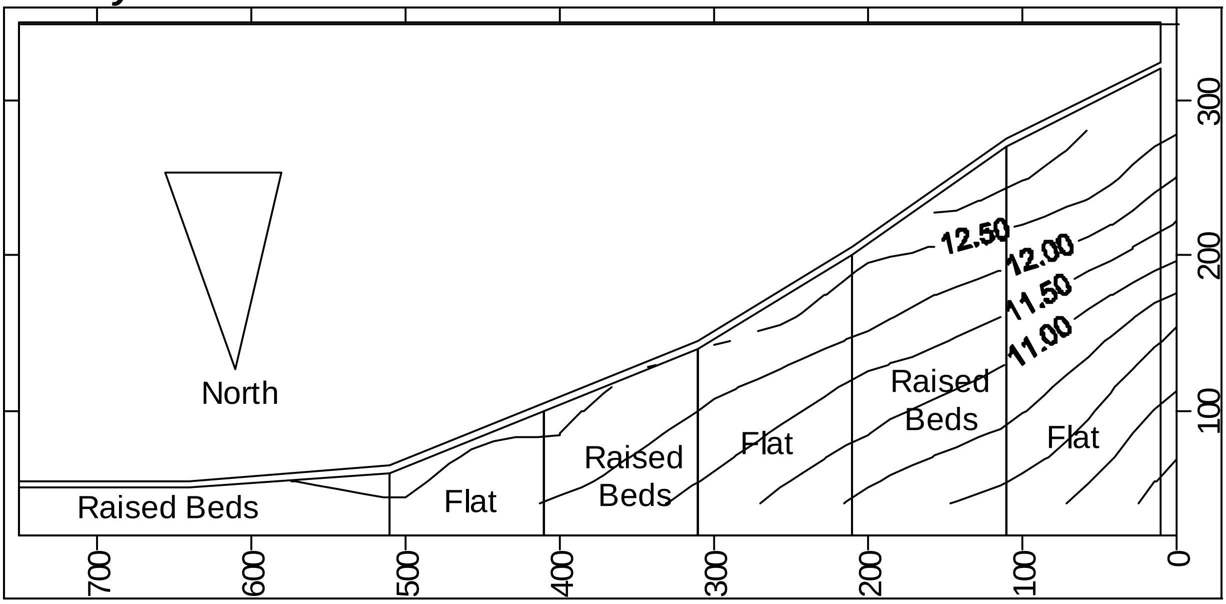

Figure 5.1 Layout of the raised beds and the control areas, 11ha.

Operations

01 May	Furrows and bed shoulders to renovate the damage done by machines with track widths different from required (1.83m or 6ft)
15 May	Ammonia Sulphate 1.5%/ha, Insecticide 70ml/ha
	Seeded. TT Canola Pinnacle 5 kg/ha + Agras 100 kg/ha
16 June	Reseeded total area, Pinnacle 4.5 kg/ha, Topdressed 60kg/ha
29 July	Sprayed Sertin Plus 500 ml/ha, Oil 1%/ha, Insecticide 70ml/ha
21 Sept	First biomass cut
21 Oct	Second biomass cut
25 Nov	Swathed with Russell's swath front
19 Dec	Harvested with Russell's header

Results

The rainfall summary during the growing season is presented in Table 5.1.

Table 5.1 Actual rainfall (from Russell) and decile ranking (between brackets) and median (Woodanilling) rainfall figures, mm.

Month	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Total, April-Nov**
Actual, mm (Decile ranking)	17 (7)	20.5 (1)	117.2 (9)	32.8 (1)	102.7 (10)	32 (4)	25.6 (5)	29.5 (8)	377.3
Median, mm	26	62	83	76	61	45	31	21	405

June and August were wetter than average whilst July was very dry. Two thirds of the rainfall which fell in June fell before the second seeding time. This was then followed by a relatively dry period which might have happered establishment during that time. The wet August resulted in some degree of waterlogging.

On this trial site, problems with seeding depth necessitated that the entire area be resown. The crop establishment remained very patchy which is illustrated by the very low plant counts on the 28th Oct (see Table 5.2)

Table 5.2 Dry matter sampling, T/ha and number of plants/m^2 Percentage difference between brackets.

	DM1, 24 Sept		**DM2, 28 Oct.**		**Plants/m^2 28 Oct.**	
Plot	**C**	**RB**	**C**	**RB**	**C**	**RB**
1	3.21	4.50	4.18	4.25	39.6	36.7
2	3.11	3.63	2.45	4.20	42.1	43.6
3	3.49	3.40	3.94	6.35	45.0	37.4
Mean	**3.27**	**3.84 (+17%)**	**3.53**	**4.93 (+39%)**	**42.2**	**39.2**
StDev	*0.20*	*0.58*	*0.94*	*1.23*	*2.7*	*3.8*
CV, %	*6*	*15*	*27*	*25*	*6*	*10*
P	*0.181*		*0.04*		*0.32*	

The very low number of plants affected the final yield, Table 5.3.

Table 5.3. Yield, T/ha

Plot	**C**	**RB**
1	0.72	0.89
2	0.60	0.91
3	0.73	0.91
Mean	**0.69**	**0.91 (+32%)**
StDev	*0.07*	*0.01*
CV, %	*10*	*1*
P	*0.006*	

This site has been the only site where the canola has been swathed. Russell swathed the crop with his own swather and dropped the swath on top of the beds. Harvesting was done with a harvester with a pickup front and wide tyres. The tyres were positioned on the top of the beds rather than in the furrows.[1]

Water logging was assessed manually and with automatic water depth recorders installed in observation wells. The depth to the perched water table as a function of time for three dip wells is presented in Figure 5.2.

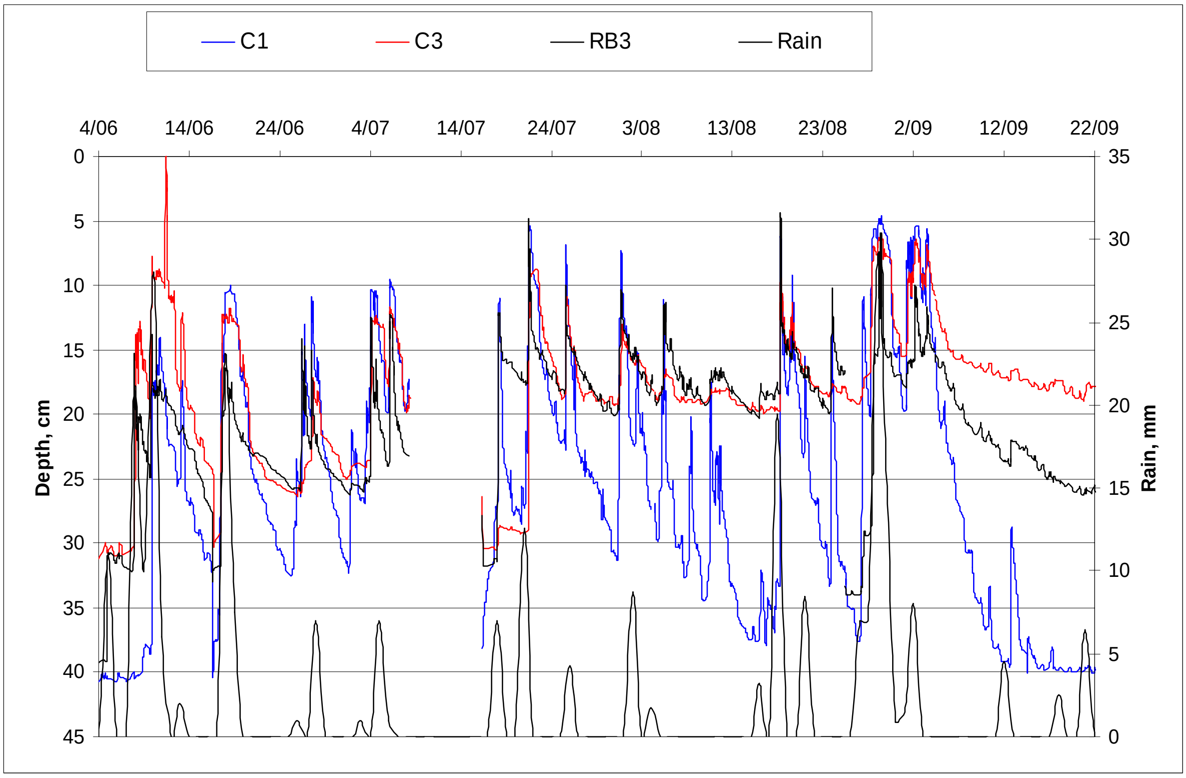

Figure 5.2 Changes in perched water table from the automatic recorders (C1,C3 & RB3).

From the figure it is clear that only during the beginning of June and late August/early September substantial waterlogging occurred (ie. the perched water table was close to the surface for several days). The difference between C1 and C3 is the depth to clay which was 40cm and 20cm, respectively. This resulted in a further draw down of the perched water table at C1 compared to C3.

[1] Although the compaction caused by this traffic appeared to be minimal, it is not recommended. The soil density changes will be measured in 1999. Eastern states farmers have ceased harvesting this way but uilize narrow tyres tracking in the furrows.

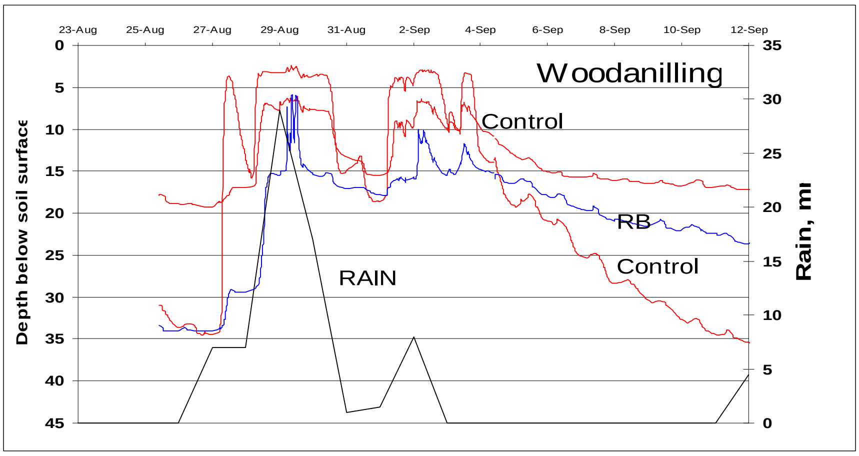

Figure 5.3 Details of the perched water table with the onset of rain.

In Figure 5.3 some details are presented that clearly illustrate the effect of the raised bed on the perched water table. As the rain moved in on the 29th of August, the perched watertable in both the raised beds and control rose rapidly. The perched watertable in the raised beds rose only to 7 and 11cm below the surface for less than a day whilst the watertable in the control remained close to the surface for several days during that period.

The soil dry bulk density is presented in Figure 5.4. The raised beds have a much less dense soil structure than the control and from 1997 to 1998 little consolidation has taken place.

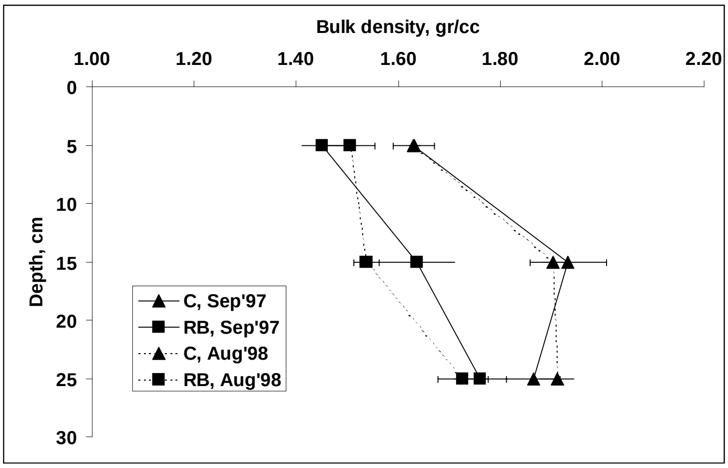

Figure 5.4 Bulk density profiles with error bars

Comments

This site had very poor crop establishment even though it was resown about the same time as Beverley and Cranbrook. Few occasions of water logging occurred during the growing season. The yield from the raised beds was higher than from the control areas. The canola was swathed and harvested with a pick-up front and wide tyres which consequently trafficked the top of some of the beds.

6. Research Experiment, "Gordon River Estate "

Mark and Clem Addis, Cranbrook. Current owners: W. A, A. G. and M. J. Armstrong

1. Paddock history

- The front of the paddock on the corner of the Albany Highway and the Frankland road has not been cropped as part of the farm rotation.
- The paddock is waterlogged for extended periods every winter and the pasture in it is of poor quality and productivity
- The Addis' are keen to expand their cropping program, and have cropped the paddock immediately upslope of this one. Cropping this paddock for our research was in their view unlikely to be successful, such is its susceptibility to severe waterlogging.
- Weed control in the paddock was not pursued whilst it was under pasture.
- In 1997 the site (raised beds and control) was cropped with oats.

Site lay-out

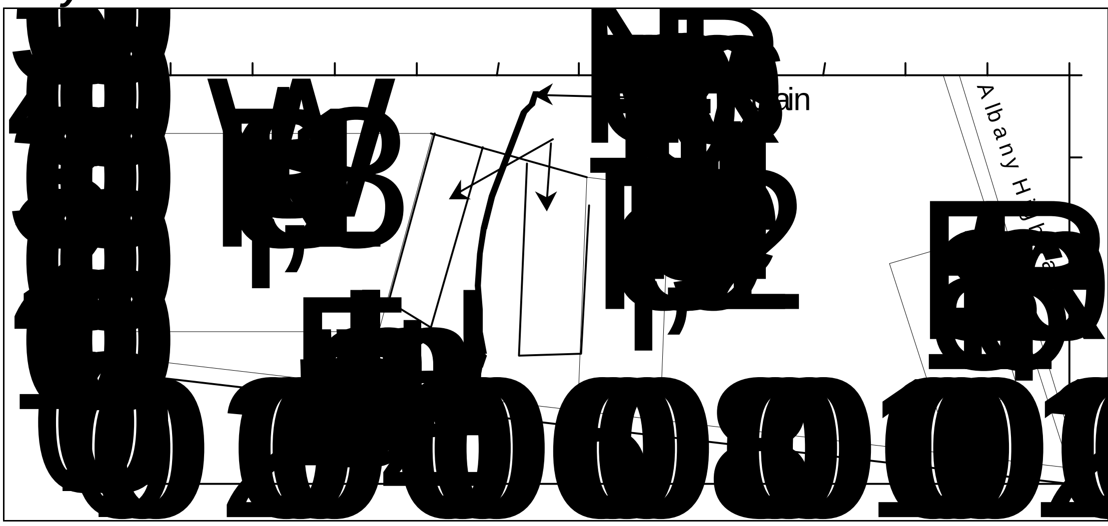

Figure 6.1 Site lay-out, illustrating the position of new bed in reps, 17 – 20, 21 ha.

Operations

19 March	Sheep in the summer grazing sections (20 sheep for 14 days)
24 April	Furrows and bed shoulders to renovate the damage done by machines with track widths different from required (1.83m or 6ft).
18 May	Roundup 2l/ha, Pulse 250 ml/ha,
	Seeded. Ti 10 Canola 5 kg/ha + Agras 150 kg/ha
	Sprayed Atrazine (2 l/ha) and Insecticide (0.5 l/ha)
17 June	Reseeded total area, Ti 10 4.5 kg/ha,
24 July	Sprayed Atraline 1.5 l/ha, Verdict 150 ml/ha + oil (0.5 ml/ha)
	Top dressed Urea 80 kg/ha
18 Sept	First biomass cut
13 Nov	Second biomass cut
21 Dec	Direct harvested

Results

The rainfall at the site is presented in Table 6.1

Table 6.1 Actual rainfall at the site, decile ranking and rainfall median from Cranbrook PO.

	April	May	June	July	Aug	Sept	Oct	Nov	Total, April-Nov
Actual, mm (decile ranking)	15 (3)	36 (3)	116.8 (10)	45 (1)	55 (4)	57 (7)	28 (3)	10 (3)	363
Median, mm	25	55	68	73	62	51	40	21	395

At the Cranbrook site June was also very wet, similar to Beverley and Woodanilling but remained substantially drier during July and August.

The plot were resown on the 17th of June under very wet conditions. One day after seeding, the site received 30 mm of rain in two days. During that time it was observed that the seed furrows on the control were carrying water whilst the raised beds remained unsaturated. Figure 6.2 illustrates this. The new plots could not be resown due to access difficulties and the results from these plots have therefore been ignored.

Figure 6.2 Runoff from the control area (A) and runoff from the raised beds (B).

The dry matter cuts (Table 6.2) were taken at regular intervals and a distinction was made between the plots which had been exposed to summer grazing and those which had not. The data analysis showed no significant difference between the grazing and the non-grazing treatment. The grazing and non-grazing results have therefore been combined.

Table 6.2 Dry matter sampling (T/ha) and plant counts, Pl/m^2. Percentage difference between brackets.

Rep	DM1, 18 Sept		DM2, 13 Nov		Plant, no/m2, 13 Nov	
	C	**RB**	**C**	**RB**	**C**	**RB**
1	1.6	2.9	6.6	6.3	34.7	41.8
2	2.0	4.3	7.8	6.9	20.9	44.9
3	2.0	2.9	6.3	7.9	16.0	72.4
4	2.5	2.0	6.5	5.7	41.3	35.1
5	3.5	3.5	8.1	5.8	42.2	25.3
6	3.7	3.2	6.1	8.4	28.0	50.2
7	3.0	3.2	11.1	8.4	31.6	40.0
8	2.7	3.1	9.0	9.2	60.4	34.7
Mean	**2.6**	**3.1 (+19%)**	**7.7**	**7.3 (-5%)**	**34.4**	**43.1**
StDev	*0.8*	*0.6*	*1.7*	*1.3*	*13.9*	*14.0*
CV, %	*29*	*20*	*22*	*18*	*40*	*33*
P	*0.19*		*0.65*		*0.2*	

In contrast with the other sites planted to canola, the RB treatment has a higher number of plants than the Control. Poor establishment on the Control due to the very wet conditions immediately after seeding resulted in very low plant number counts in some of the Control reps. Even though little difference existed between the treatments in dry matter contents, the yield of the RB treatment eventually was significantly higher, see Figure 6.3.

Table 6.3 Yield, t/ha

	Yield, (t/ha)		Oil Content (%)	
Rep	**C**	**RB**	**C**	**RB**
1	0.89	1.42	41.2	40.8
2	1.03	1.76	42.2	41.2
3	1.03	1.76	41.7	43.2
4	1.03	1.80	41.5	43.4
5	1.49	1.44	42.1	42.4
6	1.40	1.98	41.9	42.6
7	1.73	1.77	40.1	41.7
8	1.45	1.59	41.7	41.9
Mean	**1.3**	**1.7 (+31%)**	**41.6**	**42.2**
StDev	*0.3*	*0.2*	*0.7*	*0.9*
CV, %	*24*	*11*	*2*	*2*
P	*0.003*		*0.15*	

The soil dry bulk densities indicated large differences between the raised beds and the control. Summer grazing did not have an effect on the soil structure in the control but made the top soil of the raised beds more compact.

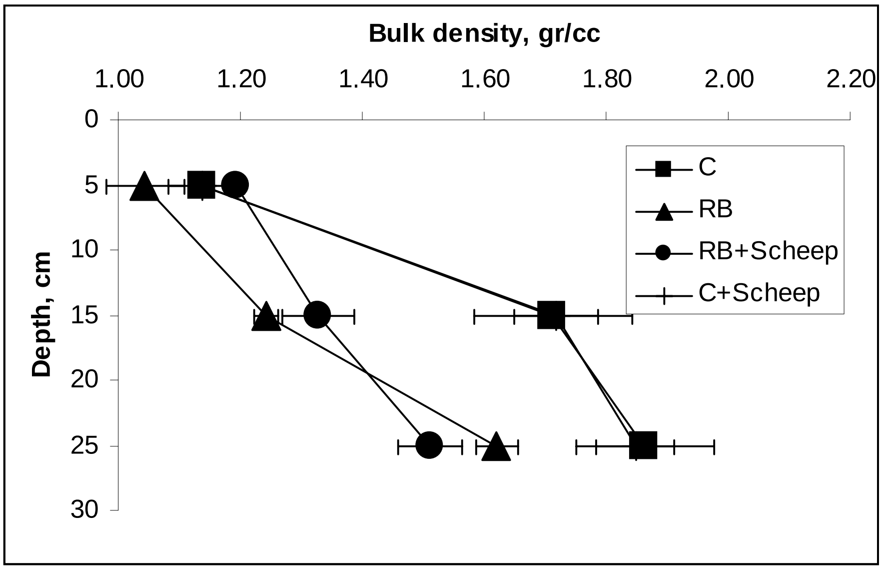

Figure 6.3 Bulk density profiles. Bulk density error bars indicate the variations.

The degrees of waterlogging was again assessed with a TDR system. From these measurements the degrees of saturation were calculated, 1 being completely saturated to 0 being dry. The degrees of saturation down the soil profile in the raised beds and the control as a function of time are portrayed in Fig. 6.4 and Fig. 6.5 respectively.

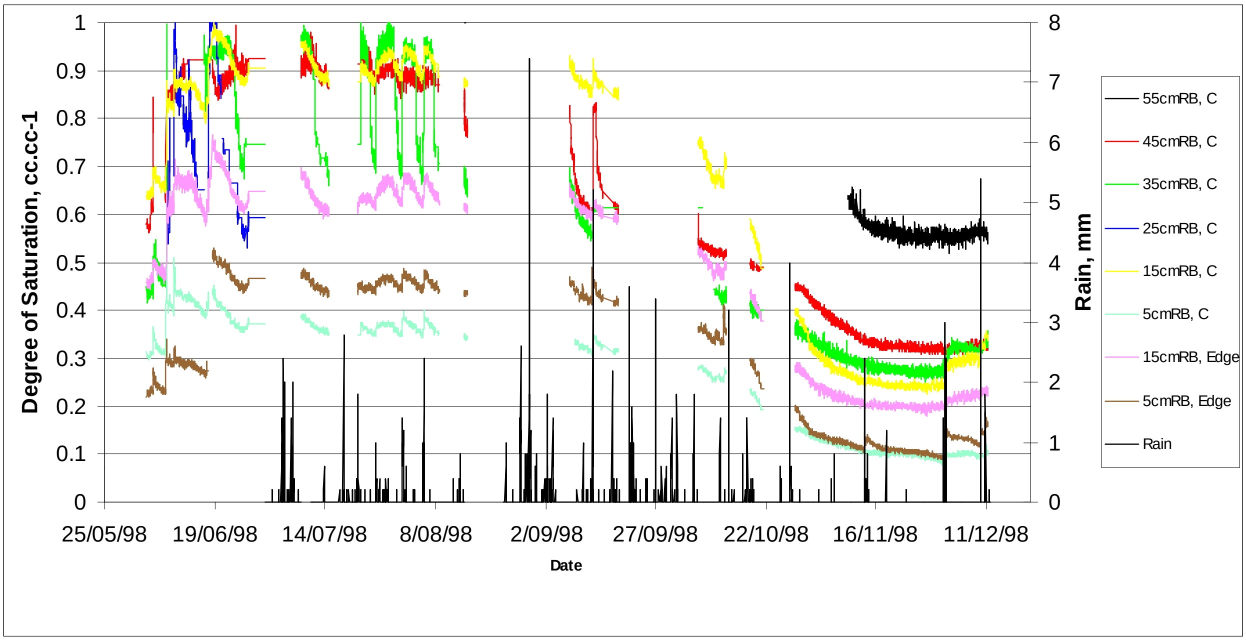

Figure 6.4 Degrees of saturation for different depths in the raised beds.

From the figure it can be seen that the sensors at a depth of 5 and 15 cm did not get saturated. At depths of 25, 35, 45 and 55 cm the soil remained close to saturation during the winter months. Even at a depth of 15cm in the centre of the bed (15cm,C) did the degree of saturation reach 0.95. The gaps in the graphs were the result of equipment failure.

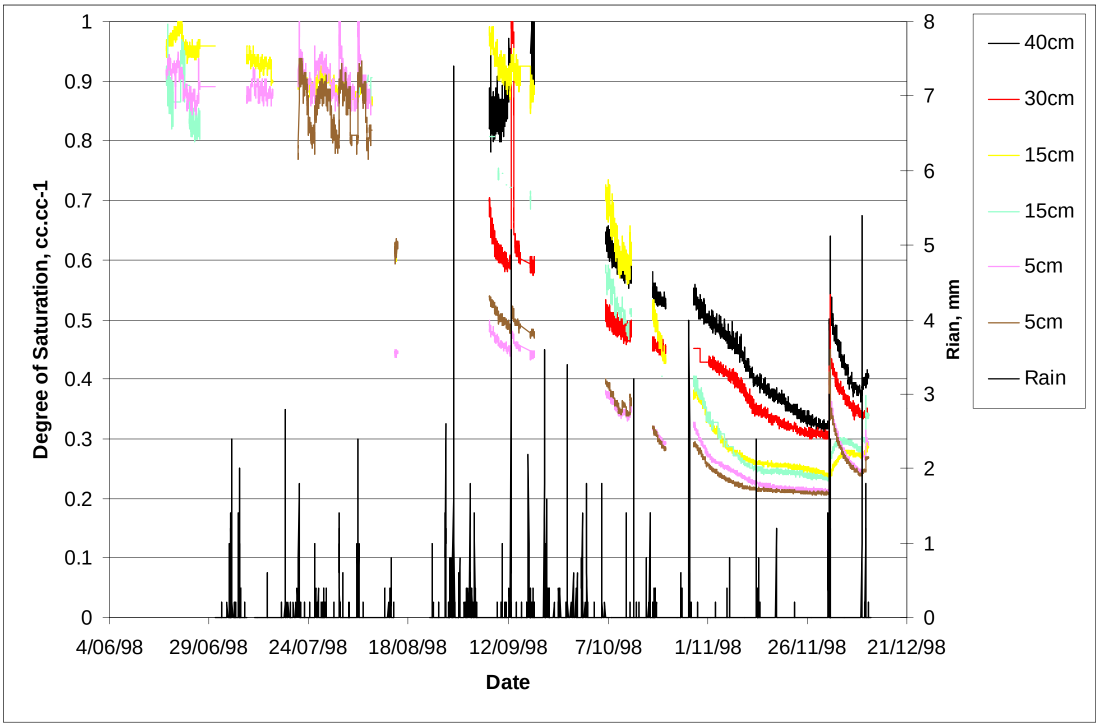

Figure 6.5 Degrees of saturation for different depths in the control.

From Figure 6.5 it can be seen that at a depth of 5 and 15 cm the soil remained in saturated conditions during most of July and August. More sensors at greater depths were added in September which indicated intially saturated conditions but then a drying profile as the season progressed.

Similar to last year, the top 15 cm of the raised beds remain unsaturated during all of the winter months in comparison to the control which remained saturated for most of those months.

Precipitation is transpirated by the crop, lost as surface runoff, evaporation from the soil or as deep drainage or recharge. The presence of the deep drainage component has been assessed with the aid of tensiometers positioned at 45 and 75cm depth. The tensiometers indicate the energy status of the soil moisture at those depths. A positive difference in the energy status between those depths indicates deep drainage whilst a negative difference indicates capillary rise.

From Figure 6.6 it can be seen that the flow both in the raised beds and the control is directed downward for most of the growing season, until the beginning of October. In the raised beds the soil moisture flow is then reversed and flows upward wilst the control continues to flow downwards. The magnitude of the difference in the control is larger than in the raised beds indicating a recharge of a larger magnitude. In the beginning of November the difference at C55-C85 increases with time which indicates that the soil layer at 85cm dried out faster than at a depth of 45cm which could not be explained.

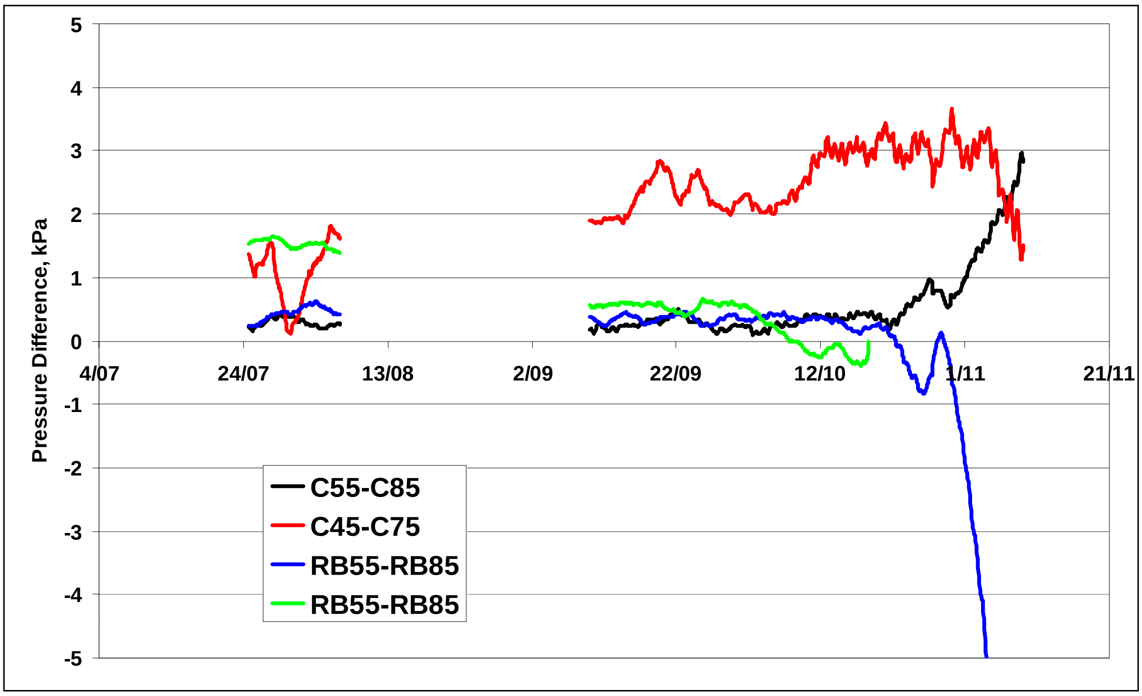

Figure 6.6 Tensiometer readings

In summary this figure seems to suggest that less recharge occurs under raised beds than under the control at least in one of the sites. Current measurements todate (Aug, '99) in Cranbrook do confirm this trend.

Similar to last year, each plot was equipped with five dip wells, distributed evenly across every plot. These wells were monitored regularly and the observed depths to the perched water table placed in various classes. A cummulative frequency distribution of the observations in the various classes is presented in Figure 6.7.

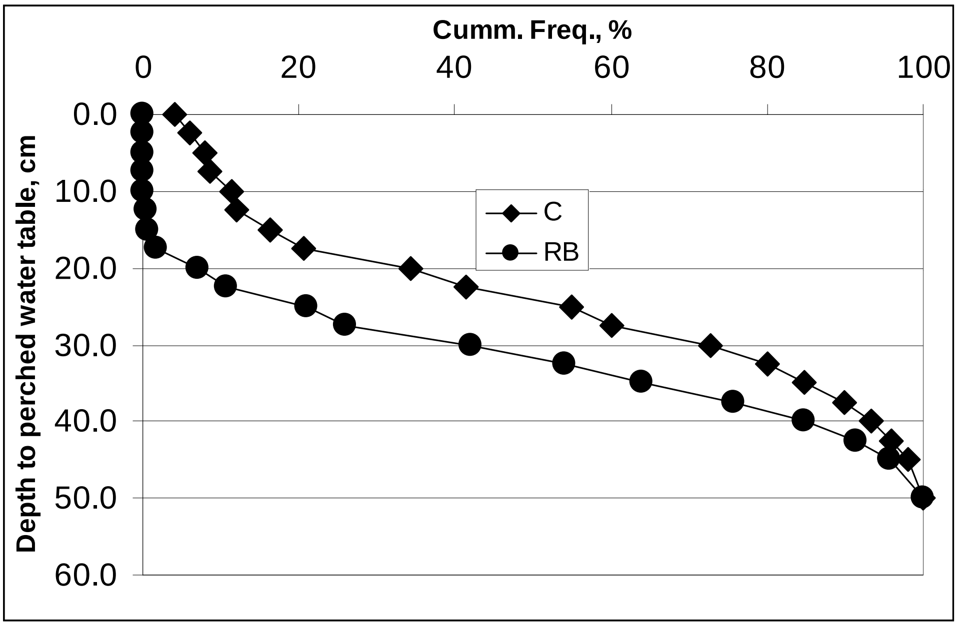

Figure 6.7 Distribution of the percentage of observation in different classes of depth to the perched water table.

Similar to last year, the frequency of observations that the depth to the perched water table is less than 20cm is negligible for the raised beds. The frequency of occurrence in the control of the same depth was much higher (i.e. more waterlogging in the control).

Similar to last year the runoff from the individual plots has been measured with the aid of weirs and flumes. The runoff was calculated as percentage rainfall runoff over the period measured (ie. 99mm). The results are presented in Table 6.4. A separation has been made between the flow over the weirs of a height of more than 0mm and of more than 50mm. The first can be seen as runoff and seepage flow (seepage + short events (high flow)) and whilst for the latter seepage flow is excluded. Only 14 of the 16 plots generated reliable information whilst plot 17 is presented seperately, due to the different layout (ie, much longer beds).

Table 6.4 Percentage rain runoff + seepage

Rep	**Treatment**	**>0MM Runoff + seepage**	**>50MM, Runoff**
1	C	16	25
2	C	17	21
3	C	39	29
4	C		
5	C	18	34
6	C	31	2
7	C		
8	C	71	75
1	RB	45	48
2	RB	72	17
3	RB	56	19
4	RB	52	12
5	RB	72	57
6	RB	48	11
7	RB	1	42
8	RB	66	3
9	RB	28	

Table 6.4b Average rain runoff (runoff and runoff+seepage)

% rainfall	C	RB
Runoff + Seepage	32	51
Runoff	31	26

From Table 6.4b it follows when only the larger flows are considered, the control is actually producing more runoff than the RB treatment. However when the total runoff (runoff +seepage) is considered the raised beds are producing more runoff. If one assumes runoff did not occur before and after the period of observations, the following percentage for runoff for the growing season rainfall (363mm) can be expected: 9% for the control and 14% for the raised beds. It is probably higher given the very wet June and see Fig. 6.2. A closer estimate is to have 80mm of the growing season rainfall stored before runoff commences (363-80 = 283mm). The growing season runoff would therefore be: 11% for the control and 18% for the raised beds.

The quality of the runoff water was assessed on various occasions by taking grab samples from the water in front of the respective weirs. The results are the mean of three samples and converted to kg/ha assuming 11% and 18% of the growing season rainfall runs off for the control and raised beds, respectively. The results are presented in Table 6. 5

Table 6.5 Nitrogen and Phosphate in kg/ha and the mean concentrations in brackets, mg/l

	N, Kg/ha	
Rep	C	RB
1	4.5	7.8
2	5.7	8.1
3	5.7	9.6
4	5.7	10.0
5	7.1	10.2
6	7.5	10.9
7	8.0	10.9
8	10.5	17.2
Mean	**6.8 (16.1)**	**10.6 (16.2)**
Stdev	*1.9*	*2.9*
CV, %	*27*	*27*
P	0.008	

P, Kg/ha	
C	RB
0.005	0.020
0.012	0.037
0.016	0.039
0.019	0.050
0.019	0.054
0.019	0.072
0.020	0.072
0.033	0.074
0.018 (0.04)	**0.052 (0.08)**
0.008	*0.020*
44	*38*
0.00042	

Highly significant differences were found between the control and the raised beds in terms of total displacement of N and P. On all occasions the nitrogen levels were too high compared to the ANZEC recommended levels which are 0.8 mg/l. The phosphates remained below those recommended levels which are 0.1 mg/l for phosphate even though fluctuations during the season were evident.

Comments

Resowing the plots under very wet conditions resulted in poor establishment of the crop in the control plots. Generally the yield in the raised beds was significantly higher than the in control. Like last year runoff was higher from the raised beds whilst remaining unsaturated during the winter months. From tensiometer observations it was concluded that the recharge under the raised beds was lower. Raised beds did affect the water quality in terms of total P and N (kg/ha) displaced from the plots.

7. Demonstration Trial "Manarup Annex",

Mount Barker Research Station

Paddock history

- The M2 paddock has been cropped regularly as part of the farm rotation of 3 crops : 3 pastures.
- A small area (0.2ha/rep) with raised beds were installed on this paddock in 1996 with vegetable equipment.
- In 1996 the trial area was sown to Barley and yielded 2.2 t/ha on the raised beds and 1.48 t/ha on the control in a season with prolonged waterlogging. (A plot harvester was used in '96)
- In 1997 this trial was sown to oats and the raised beds yielded less than the control areas, 2.00 t/ha vs 2.59 t/ha. This result was not supported by the dry matter content taken during the growing season which showed a trend in favour of the raised beds. The plots were harvested with a large header and the yield was obtained from the yield monitor. It is likely that this method masked the real yield from each treatment.
- In 1998 the plots were chisel ploughed and completely reformed with larger equipment while the area was extended.

Site lay-out

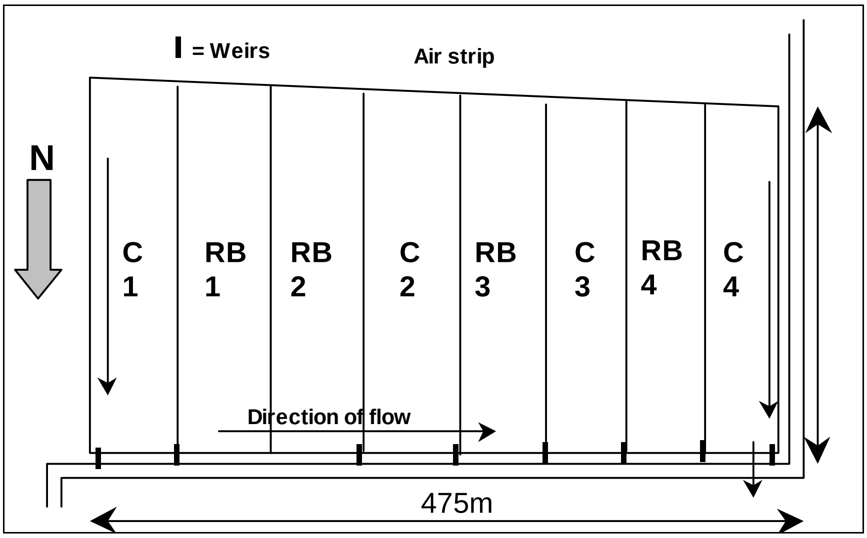

Figure 7.1 Lay-out of the raised beds trial at the MBRS, 12ha.

1. Operations

23 March	Mounded the raised beds
21 May	Sprayseed 1 L/ha, Logran 30gr/ha
23 May	Seeded, Wheat 1379 75 kg/ha
	Agras 150 kg/ha
17 July	Top dressed Urea 80 kg/ha, plant count
20 July	Weed control. Eclipse 5gr/ha + Oil 500 ml/ha
19 Sept	First biomass cut
29 Oct	Second biomass cut
15 Jan	Harvested

Results

The year started with a dry May, a wetter than average June but then a dry July. In all the sites July has been drier than average. August and September remained average whilst October and November were very dry.

Table 7.1 Rainfall summary for Manarup

Month	April	May	June	July	Aug	Sept	Oct	Nov	Total, April-Nov
Actual, mm (Decile ranking)	55 (7)	32 (1)	125 (10)	64 (2)	96 (7)	88 (7)	22 (1)	8 (1)	490
Median, mm	46	87	97	107	91	80	71	35	585

A soft seedbed and poor depth control of the seeder resulted in very deep seed placement on the raised beds and therefore very poor plant establishment. This is illustrated by the low plant counts found in the raised beds almost two months after seeding.

Table 7.2. Plant count, pl/m^2.

Plot	C	RB
1	84.75	69.75
2	86.5	63.25
3	89.25	63.25
4	100	67.25
Mean	90.1	65.9
Stdev	*6.8*	*3.2*
CV, %	*7*	*5*
P	0.0006	

Despite the very poor plant establishment on the raised beds at the first and the second dry matter cut the raised beds had produced a better crop which only got better in time (ie. percent difference increased from 4 to 15%).

Table 7.3 Dry matter content, t/ha. *n* = 5. Increase in percentage between brackets.

DM 1, 19 Sept			DM 2, 29/Oct		
Rep	C	RB	Rep	C	RB
1	1.15	1.53	1	2.48	3.51
2	1.22	1.24	2	2.77	3.63
3	1.63	2.04	3	4.48	5.12
4	1.92	1.35	4	5.94	5.77
Mean	1.48	1.54(+4%)	Mean	3.92	4.51(+15%)
Stdev	*0.36*	*0.35*	Stdev	*1.61*	*1.12*
CV, %	*24*	*22*	CV, %	*41*	*25*
P	*0.82*		P	*0.57*	

This increase in dry matter production was not sustained until harvest during which the increase in yield on the raised beds was reduced to 9%. The dry finish to the season (October, November) undoubtedly reduced the difference between the raised beds and the control. A large problem were also the weeds. Particularly in the raised beds (Rep 1) was the pressure high. This might explain the low yield in that rep. It was also noticed that a lot of water weeds were present in the furrows which were very wet for extended periods. Figure 7.2 and 7.3 illustrate the weed burden.

Figure 7.2 An open furrow susceptible to weed infestations.

Figure 7.3 Weed infestations on the raised beds

Table 7.4 Yield, t/ha

Rep	C	RB
1	1.30	1.45
2	1.25	2.06
3	2.12	2.26
4	2.86	2.44
Mean	**1.88**	**2.05 (+9%)**
Stdev	*0.76*	*0.43*
CV, %	*40*	*21*
P	*0.71*	

Grain quality testing did not reveal any differences between the grain from the control and the raised beds even though the raised beds seem to have a higher incidence of fungal staining for some unknown reason.

There were three observation wells in each replicate. These were monitored manually to establish the depth to the perched water table. The observed depths to the perched water table was placed in various classes, the distribution of the number of observation in these various classes is presented in Figure 7.4.

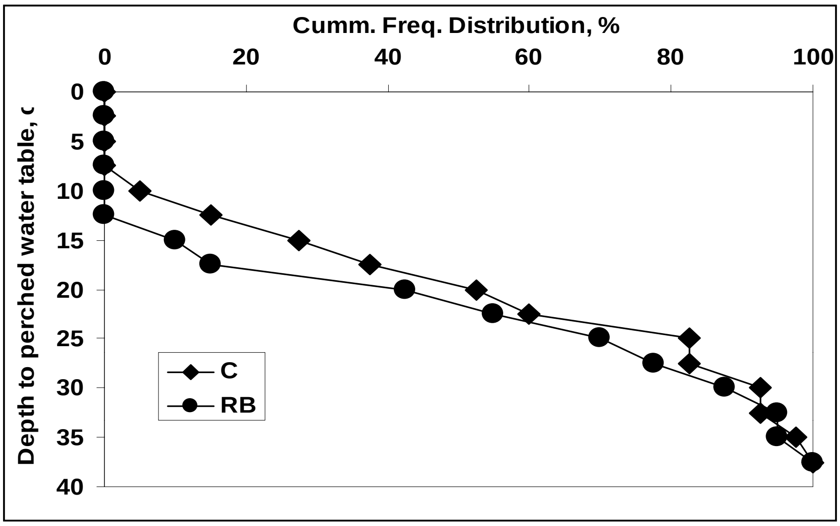

Figure 7.4 Cummulative distribution of the observations in the various classes.

As expected, the control had more observations in the shallower depths than the raised beds. The total number of observations at the MBRS has been fairly limited and no measurements were done during or shortly after rainfall event. Higher values which were expected particularly in the control, were not present.

Runoff data from the plots presented in Table 7.5 were calculated from the runoff flows across rectangular weirs positioned in the catch drain at the bottom of the plots as indicated in Figure 7.1.

Table 7.5 Percentage rain runoff for individual rainfall events, mm and growing season runoff

Period	C, %	RB, %	Rain, mm
4/7-10/7	41	61	27
26/7-30/7	19	40	20
31/7-3/8	34	50	14
5/8-6/8	18	49	11
28/8-31/8	23	39	27
2/9-6/9	35	25	29.5
12/9-14/9	12	10	19
21/9-25/9	40	34	14
Mean	28	38	
Stdev	11.1	15.7	
Growing season rainfall runoff	11	15	

The runoff has been of the same magnitude as the runoff in Cranbrook. In some instances the flow was too large for the weirs to handle and water crossed the adjacent road. This would account for some of the losses during the heaviest rainfall events. The final runoff figures might therefore have been slightly higher.

The soil dry bulk density showed large differences between the control and the raised beds (Figure 7.5). At depth of 0 – 1cm and 10 – 20cm the differences were significant (P<0.05). It can be seen that the seed bed has been extremely loose (0.93 gr/cc), up to the point that it was difficult to walk on.

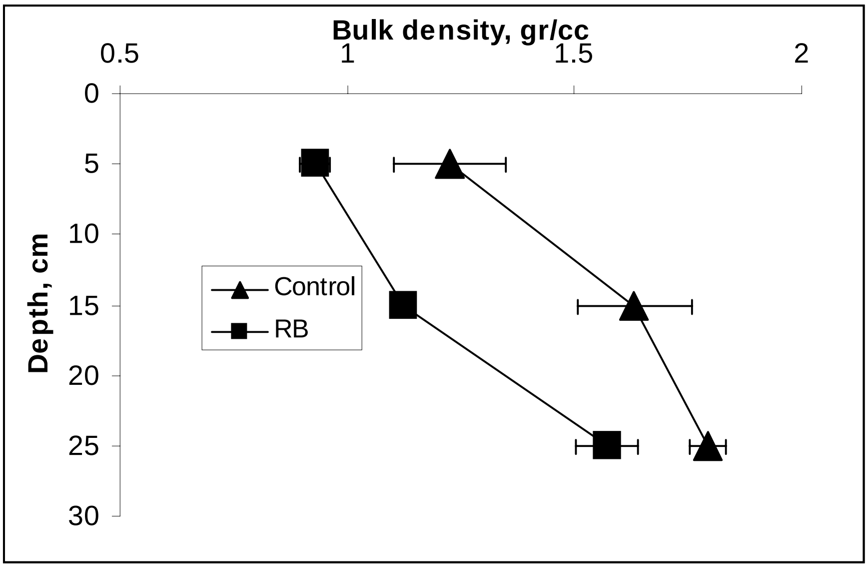

Figure 7.5 Bulk density, gr/cc with error bars

Comments

Poor crop establishment affected canopy closure and increased the weed burden on the raised beds. The raised beds produced more runoff than the control. It was observed that theraised bed furrows which were constantly wet during the winter months encouraged the development of water weeds in the furrows. Despite some of the set backs in the raised beds, the final yield was still higher than the control.

8. Demonstration Trial, "EDRS"

Esperance Downs Research Station

Paddock history

- The demonstration site is located on the western edge of the EDRS.
- This site was renovated and enlarged in 1998. The raised beds in 1997 were installed with a small implement, similar to the one used in 1996 at the MtBarker Research Station. These were considered unsatisfactory and, so, the site was chisel ploughed and beds reconstructed with the larger Gessner furrower/bedformer.

Site lay-out.

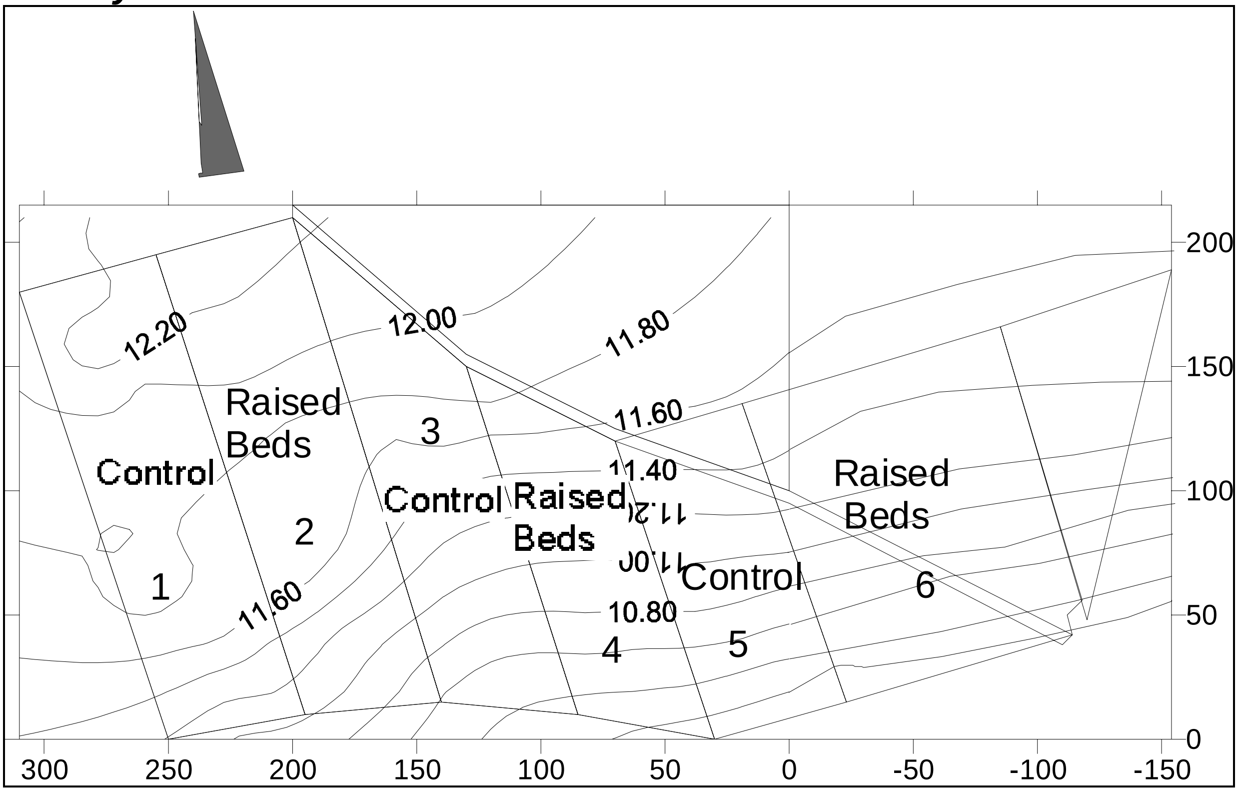

Figure 8.1 Lay-out of the raised bed trial at the EDRS, 13ha.

Operations

22 June 1998 Deep Ripped
23 June 1998 Mounded the raised beds
24 June 1998 Seeded Canola 5 kg/ha
Dap & Impact 80 kg/ha
Sprayed, Atrazine 1.5 l/ha, Telstar insecticide 100 ml/ha
3 Aug 1998 Sprayed Atrazine 1.5 l/ha, Fusilade 250 gr/ha, Oil 1%/ha, Wetting agent 200ml/100lt
4 Aug 1998 Top dressing, Urea, 80 kg/ha
17 Sept 1998 First dry matter sampling
13 Oct 1998 Second dry matter sampling
30 Nov 1998 Direct harvest

Results

The rainfall summary is presented in Table 8.1. From the comparison between the actual and the long term average rain fall summary it is concluded that the 1998 growing season has been an average year. May was slightly drier than average whilst July was average and August drier than average. The end of the season (Sept, Oct and Nov) was generally an average season without too much waterlogging if any.

Table 8.1 Rainfall summary

Month	April	May	June	July	Aug	Sept	Oct	Nov	Total, April-Nov
Actual, mm (decile ranking)	44 (7)	37 (2)	67 (4)	97 (6)	51 (2)	52 (5)	46 (5)	23 (4)	418
Median, mm	36	73	76	89	76	60	49	30	489

Toward the end of July one rainfall event caused some degree of waterlogging as the following figures illustrate but the effect of the waterlogging was not severe enough to cause major damage to the crop.

Figure 8.1 Water logging in the control after 40 mm of rain over three days in July

Figure 8.2 No water logging on the raised beds after 40 mm rain over three days in July.

When this trial was sown depth control problems were avoided by carrying the seeder on the 3-point linkage and the eliminated from the seeder thus ensuring proper seeding depth in the control and the raised beds.

The mean first dry matter content obtained from the control was significantly higher ($P<0.05$) than from the raised beds. Also for the second sampling the control had a higher dry matter content than the raised beds even though not significant (P= 0.81). This difference was caused by the lower number of plant in the raised beds, see Table 8.2.

Table 8.2 Plant count, pl/m^2

Rep	C	RB
1	108.9	64.9
2	60.9	53.8
3	81.8	38.2
Mean	83.9	52.3
Stdev	*24.1*	*13.4*
P	*0.11*	

Table 8.3 Dry matter contents, t/ha

	DM1 1, 17 Sept				DM2, 13 Oct.	
Rep	C	RB		Rep	C	RB
1	2.31	1.84		1	5.8	6.2
2	2.28	1.83		2	5.3	4.9
3	2.12	1.93		3	4.8	4.4
Mean	2.24	1.87 (-17%)		Mean	5.3	5.2 (-2%)
Stdev	0.10	0.05		Stdev	0.5	0.9
CV, %	4	3		CV, %	9	17
P	0.005			P	0.81	

At harvest time the yield (Table 8.4) of the raised beds outperformed the control (P = 0.06) whilst the oil content on the raised beds was reduced and substantially different from the control (P = 0.07).

Table 8.4 Yield, t/ha and oil content, %

Yield

Plot	**C**	**RB**
1	2.40	2.26
2	2.12	2.16
3	1.99	2.19
Mean	**2.17**	**2.20 (+1%)**
Stdev	*0.21*	*0.05*
CV, %	*10*	*2*
P	*0.06*	

Oil

Plot	**C**	**RB**
1	42.4	40.6
2	41.9	41.7
3	41.7	40.7
Mean	**42.0**	**41.0**
Stdev	*0.36*	*0.61*
CV, %	*1*	*1*
P	*0.07*	

The individual plants on the raised beds were larger with a much more developed root system than the plants growing on the control as shown by Figures 8.3 and 8.4.

Figure 8.3 Root development in the control and the raised beds.

The runoff from four plots was measured using 'V'-notch weirs, positioned on the plot boundaries and the results are presented in Table 8.5

Table 8.5 Runoff data from the control and raised beds

Period 25/06 – 25/09	C	RB
Rain: 213 mm	8.2 mm	18.0 mm
% Rain runoff	4	9
% Growing season rainfall runoff	2	4

Very little runoff compared to the MBRS and the Cranbrook sites was recorded whilst the presence of the raised beds increased the amount of runoff.

The soil bulk density is presented in Figure 8.4. It was found as in the other sites that the raised beds had a much less dense soil structure than the control. It should be noted that after deep ripping with an Agro plough and mounding the density of the soil of the raised bed at the EDRS was higher in the top 10cm than at the MBRS, 1.21 and 0.93 gr/cc respectively, whilst the soil type was fairly similar (ie. gravelly sand on clay).

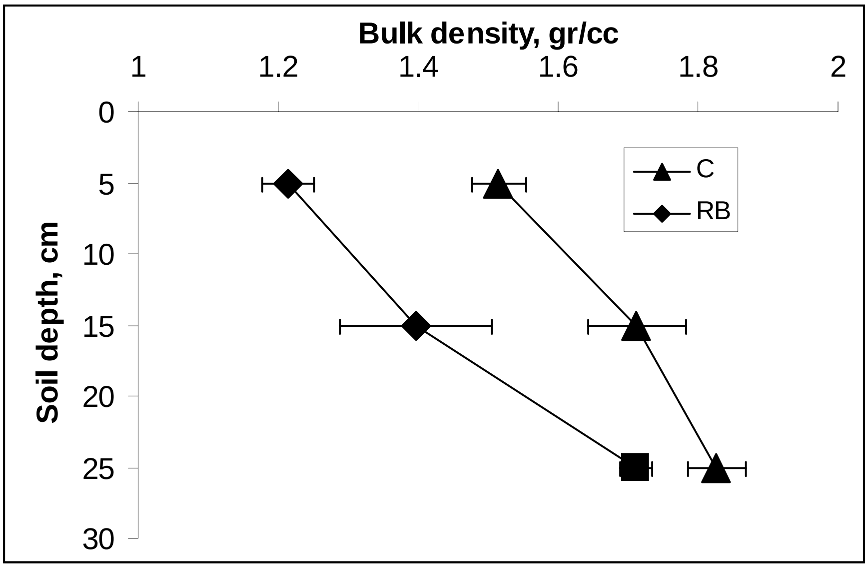

Figure 8.4 Bulk density, gr/cc, with error bars.

Comments

Little waterlogging and an overall good growing season minimised the difference between the treatments, even though the yield from the raised beds was obtained from a lower number of plants. A later anthesis on the raised beds affected the oil content but the overall favourable growing conditions in the raised beds increased the yield. Generally very little runoff occurred from this site with a slight increase from the raised beds.

9. 1998 Data Analysis – All Sites

Introduction

Of the 1997 sites, MBRS and EDRS sites were renovated and enlarged whilst two more sites added, Toolibin (60ha) on a grey clay flood plain and at Quairading, a valley floor and a salt scald. Waterlogging at any of the sites in the 1998 season was not severe in either frequency or intensity.

Soils

The soil and the median growing season rainfall at the sites are as follows:

Quairading: sandy loam (20 cm) over clay, situated in a valley floor which showed signs of degradation due tot salinity.
Median growing season rainfall: 287 mm

Beverley: 10 cm of dispersible sandy clay loam over dispersible medium-heavy clay;
gypsum at 4.7 t/ha was incorporated into the raised beds
Median growing season rainfall: 338 mm

Toolibin: shallow sandy clay loam over dispersible medium-heavy clay, gypsum at 3.7 t/ha has been applied and incorporated into the raised beds
Median growing season rainfall: 329 mm.

Woodanilling shallow sandy loam over clay of varying depth. Gypsum was applied at a rate of 2.3 t/ha. on the raised beds which were installed after deep ripping and chisel ploughing.
Median growing season rainfall: 405 mm

Cranbrook shallow sand over gravel (~ 60%) over clay. At depth (70cm) a duricrust is present which forms a very hard layer. No gypsum was applied. The site was extended to incorporate newly made raised beds of a longer length.
Median growing season rainfall: 395 mm

MBRS shallow sand over gravel (~40%) over clay. The site was extended substantially without incorporating different soil types. Degrees of waterlogging appeared not to be as severe at the western end of the site. The raised beds were deep ripped and chisel ploughed prior to installation of the beds
Median growing season rainfall: 585 mm

EDRS shallow sand over gravel over clay. The site was also extended significantly without incorporating new soil types. The raised beds were deep ripped with an Agrow plough and chisel ploughed prior to installation of the beds.
Median growing season rainfall: 489 mm

Seasonal Conditions

Rainfall summary

Table 9.1 Rainfall summary, 1998

Location		April	May	June	July	Aug	Sept	Oct	Nov	April-Nov total
Quairading	Actual	37	13	97	55	57	25	5.5	12	301
	Decile ranking	*8*	*2*	*8*	*5*	*8*	*5*	*2*	*6*	
Quairading shire	*Long term median*	*14*	*50*	*67*	*57*	*47*	*26*	*16*	*10*	*287*
Beverley	Actual	27	30.8	83.8	42.6	61.8	36	11.4	10	266
	Decile ranking	*7*	*3*	*6*	*2*	*6*	*6*	*3*	*6*	
Beverley PO	*Long term median*	*18*	*52*	*78*	*71*	*57*	*34*	*19*	*9*	*338*
Toolibin	Actual	58	34.5	68.5	46	87	17.5	13.5	9	325
	Decile ranking	*10*	*3*	*6*	*3*	*9*	*2*	*4*	*3*	
Wickepin PO	*Long term median*	*22*	*50*	*69*	*68*	*47*	*37*	*22*	*13*	*329*
Woodanilling	Actual	17	20.5	117.2	32.8	102.7	32	25.6	29.5	377
	Decile ranking	*4*	*1*	*9*	*1*	*10*	*4*	*5*	*8*	
Woody PO	*Long term median*	*26*	*62*	*83*	*76*	*61*	*45*	*31*	*21*	*405*
Cranbrook	Actual	15	36	116.8	45	55	57	28	10	363
	Decile ranking	*3*	*10*	*1*	*4*	*7*	*3*	*3*		
Cranbrook PO	*Long term median*	*25*	*55*	*68*	*73*	*62*	*51*	*40*	*21*	*395*
MBRS	Actual	55	32	125	64	96	88	22	8	490
	Decile ranking	*7*	*1*	*10*	*2*	*7*	*7*	*1*	*1*	
MtBarker	*Long term median*	*46*	*87*	*97*	*107*	*91*	*80*	*71*	*35*	*585*
EDRS	Actual	44	37	67	97	51	52	46	23	418
	Decile ranking	*7*	*2*	*4*	*6*	*2*	*5*	*5*	*4*	
EDRS	*Long term median*	*36*	*73*	*76*	*89*	*76*	*60*	*49*	*30*	*489*

b) Comments on Seasonal Conditions

Quairading

This site had a dry start to the season with a much drier than average May whilst June received more than average rainfall. Most of this rainfall occurred shortly after seeding. July was slightly drier whilst August was slightly wetter than average. The finish to the season was again much drier than average. Apart from the wet spell in

June, no major waterlogging event occurred on this site. The combined effect of waterlogging and salinity was not severe, and reasonable yields were obtained on the control.

Beverley
Had a dry start to the season (May), followed by an average June, a dry July and an average remainder of the growing season. A few minor waterlogging events occurred toward the end of August, but from the growing season total it can be concluded that the season has been relatively dry. Therefore the benefits of the raised beds were not expressed as they could have been.

Toolibin
Last year saw a below average rainfall for most of the season with an above average rainfall in August when the drains were running on only one occasion. This was followed by a dry Sept. The effect of the raised beds on the crop would therefore have been limited to the deep tillage effect of the beds. This was reduced by the large rye grass population on the beds.

Woodanilling
A dry May but a very wet June was followed by a dry July, a wet August and an average September and October. According to our observations three waterlogging events occurred during which the raised beds were void of any waterlogging. The poor crop establishment would have been the overriding factor affecting the crop yield in this site rather than other factors such as waterlogging.

Cranbrook
A dry May and a wet June was followed by a dry July and August, fairly similar to Woodanilling. The dip wells and the soil moisture sensor observations clearly indicated the absence of waterlogging in the raised beds during the growing season while the furrow carried the runoff away from the bed quite frequently. The runoff was measured from the individual plots over the period: 26 June to 05 Oct., 32% and 51% rainfall runoff was measured for the control and the raised beds respectively. Over that period in 1998, 148 mm fell compared to 221 mm which fell in the same period in 1997.

Mount Barker Research Station
The dry start in May was also followed up by a wetter than average June and than a dry July. Waterlogging occurred on various occasions, particularly in the control with both the raised beds and the control generating runoff. It was noticed that the furrows continued to run water (ie. seepage) for extended periods which encouraged water weeds in the furrows. The MBRS site received by far the most rainfall (490 mm) and this site would have been the only one where extended wetness of the furrows would have been an issue.

Esperance Downs Research Station
Esperance received average rainfall in July while August was drier than average. Only on a few occasions was waterlogging an issue but not to the extent to cause visual damage to the crop. Little runoff was recorded across the weirs.

The major rainfall event in Jan 1999 (one in 200 year) during which the 167 mm was recorded over a 3 day period did produce a lot of runoff but did not cause any damage to the furrows or beds other than re-aligning some stubble in the furrows. No sign of erosion was visible.

Production data

a) Plant populations

Plant populations were determined during the second dry matter content sampling, usually done in October. It was noticed that only in the raised beds, plants had been eliminated from those furrows which were trafficked during spraying and the fertiliser application after seeding. Both applications have a width of 10m and the same furrows were trafficked during these applications. It was also noted that the impact of the wheel traffic on the control was not as pronounced as in the furrows. This can be explained as follows. There is a good chance that in the control not the same wheel tracks are used during those applications, each area is therefore trafficked only once, the top soil of the control is often drier than the furrows and the top soil in the control is usually of a lighter soil texture than the furrows. These three conditions result in less damage to the crop in the control when trafficked than the furrows of the raised beds. Canola, being a dicotyledoneous plant, is particularly susceptible to traffic compared to, for example, wheat (a monocotyledoneous plant). It is calculated that 37.5% of the area is trafficked at seedling stage, assuming a 100% mortality in the trafficked furrows a 37.5% lower plant count can be expected in the raised beds. In the dry matter sampling using 5 samples per rep, it was ensured that about 2 out of the 5 (ie 40%) would include a trafficked furrow. In this way sampling would reflect the situation in the field. From Table 9.2 it can be seen that a ≈40% lower plant count in the RB treatment was found in Beverley and Esperance but not in Woodanilling and Cranbrook. Cranbrook had a very poor establishment on the control whilst Woodanilling overall had a very poor establishment. Poor germination in the furrows was not evident in Toolibin (Oats) or MBRS (Wheat). Dry matter and the final yield at all sites is presented in Table 9.3 and 9.4, respectively.

Table 9.2 Mean plant populations, pl/m2 for the sites planted to canola

Location	Crop	C	RB	% difference
Quairading	Barley	n.m.	n.m.	
Beverley	Canola	108	63	-42
Toolibin	Oats	113	128	+13
Woodanilling	Canola	42	39	-7
Cranbrook	Canola	31	38	+22
MBRS	Wheat	90	66	-27
EDRS	Canola	85	52	-39

n.m.: not measured

a) Dry matter

Table 9.3 Dry matter production, t/ha, taken in September and October

Location	Crop	September			October		
		C	RB	% difference	C	RB	% difference
Quairading	Barley	n.m.	n.m.		n.m.	n.m.	
Beverley	Canola	3.64	3.53	-3	4.28	4.20	-2
Toolibin	Oats	4.53	7.36	+62	6.49	8.86	+37
Woodanilling	Canola	3.27	3.84	+17	3.53	4.93	+40
Cranbrook	Canola	2.85	3.14	+10	8.06	7.83	-3
MBRS	Wheat	1.48	1.54	+4	3.92	4.51	+15
EDRS	Canola	2.24	1.87	-17	5.30	5.20	-2

n.m.: not measured

Table 9.4 Mean grain yield, T/ha

Location	Crop	C	RB	% difference
Quairading	Barley	2.11	2.27	+8
Beverley	Canola	0.98	0.94	-4
Toolibin	Oats	2.09	2.24	+7
Woodanilling	Canola	0.69	0.91	+32
Cranbrook	Canola	1.22	1.62	+33
MBRS	Wheat	1.88	2.05	+9
EDRS	Canola	2.17	2.2	+2

Comments

Quairading

Delayed germination on the raised beds and lack of waterlogging conditions in the control minimised the expression of the raised bed benefits. However, despite the higher salt levels in the raised beds, they did improved the yield by about 0.16 t/ha

Beverley

The raised beds were re-sown four weeks later due to poor establishment through poor depth control and seeding too deep. Throughout the growing season the control had a higher productivity than the raised beds which can be contributed to the difference in seeding time and lower plant numbers. Lack of waterlogging conditions during the growing season in the control ensured that the control maintained this production advantage. The below average growing season rainfall produced an average crop of less than 1 t/ha. It should be noted that the 0.94 t/ha from the raised beds was obtained from a much lower number of stalks compared to the control, 63.3 vs. 107.8 plants/m2. The plants on the raised beds were larger and had a better developed root system.

Toolibin

The very dry finish to the season was not able to sustain the large dry matter advantage of the raised beds. As the season progressed the advantage reduced from 62% in September to 36% in October to a 7% yield advantage in November. Considerable weed competition occurred in the RB's and late in the season the competition from ryegrass for the limited available soil moisture probably reduced the yield.

Woodanilling

Reseeding of the entire area after one month was also necessary on this site but plant numbers were severely affected, 42 and 39 plants/m^2 for the control and raised beds respectively. These are both well below the optimum plant densities of 80 – 100 pl/m^2. The productivity increase from September to October was marginal compared to Cranbrook or Esperance probably because of the dry finish to the season combined with the late sowing. The poor final yield was further depressed by delayed harvesting. Logistical arrangements delayed harvesting of swaths and an undetermined seed loss occurred from opened pods.

Cranbrook

Reseeding was also done in Cranbrook, one month after the first attempt. The conditions during the second seeding were very wet in the control which affected the crop establishment and therefore the plant numbers. This was confirmed by the plant counts in October. The season progressed very well with a very good increase in dry matter from September to October, following the good average rainfall in September. The plant numbers were very low compared to the optimum numbers (80-100pl/m^2) but the yield difference was much greater then the dry matter difference indicated, particularly in light of the dry finish.

Mount Barker Research Station

Seed placement in the raised beds had been too deep for wheat which caused a delay in the germination and a low germination count. Combined with the large weed burden on the raised beds in particular, the potential yield of the wheat was severely affected. However waterlogged conditions which visually affected the control areas, albeit very localised, were absent in the raised beds and out-yielded the control by 0.17 t/ha.

Esperance Downs Research Station

Seeding depth on the raised beds was much improved, resulting in a good uniform plant stand on the raised beds even though the numbers were still below the optimum. There was a visual difference in plant and crop development in favour of the beds but this was not translated into a large difference in yield. During the season, the differences in the dry matter in favour of the control reduced to a point where the yield of the raised beds was higher than the control. Optimum weather conditions and a lack of waterlogging events produced a good crop in the control. A substantial increase in dry matter production from September to October was indicative of the ideal seasonal conditions compared to eg. Beverley or Woodanilling.

Conclusion

All sites except EDRS had a very dry Oct., evidence that, despite drainage and aeration of the raised beds, the drier root zone and deeper rooting development of the plants on the raised beds provides comparatively better finish to crops than is possible with wetter root zone and small root development of plants in the Control treatments. Despite some major difficulties with seed placement, late seeding, below optimum plant numbers and a high weed burden on the raised beds, the average yield from the raised beds was improved by 9% compared to the control. This has occurred in a wide range of climatic conditions and for different crops and increases our confidence in the robustness of the raised bed system as a soil management tool to eliminate waterlogging and improve productivity.