FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

SDI00008

Non-wetting management options

PROJECT DETAILS

PROJECT CODE:	SDI00008
PROJECT TITLE:	NON-WETTING MANAGEMENT OPTIONS
START DATE:	16.06.2015
END DATE:	16.06.2015
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Summary

Water repellence (non-wetting) is a high risk in the Albany Hinterland, Esperance Sandplain and Fitzgerald Biosphere sub-regions and a moderate risk in the Kent-Frankland and Pallinup North Stirlings sub-regions (Natural resource management issues for the South Coast Regional Strategy, March 2005).

Most farms on the lighter soil types through these districts have an area of non-wetting soil and continued cropping intensity has led to many of these soil types seeing increased incidence of non-wetting. More recent anecdotal evidence shows that the non-wetting issue is becoming worse under a 100% cropping system (no till and retaining all stubble). In addition, the tendency to bring the time of sowing forward has increased the incidence of non-wetting.

Non-wetting soils result in poor and uneven water penetration on dry soils causing staggered plant germination. Delayed germination limits yield potential and creates difficulties in spray application timings. Weed germinations are delayed creating weed control issues especially with soil applied herbicides such as trifluralin# on ryegrass. Patchy germination also contributes to wind and water erosion. The effects last well into the season and early germination losses are not recoverable.

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Conclusions

The addition of clay, even at low rates of 75t/ha and 150t/ha, has been very effective in increasing the yield from an average 2.45t/ha of the control to about 2.95t/ha. It is expected that claying will have a long lasting effect and that the yield increases compared to the control will remain.

The mouldboard ploughing (MBP) and the spaded plots were located in an area of the trial site where shallow clay was brought up to the surface which affected crop establishment and thus yield. It was noted, however, that the additional cultivation enabled deeper root penetration and development of larger plants and thus the MBP still had a respectable yield of 3.01t/ha compared to 2.75t/ha and 2.5t/ha on the left hand side and the right hand side, respectively.

The other treatments, such as on-row and off-row seeding and banding, all yielded in the general range of variability of the control treatment. Judging from the lack of differentiation in the soil moisture in the seed row and in the old stubble row (Fig. 7), a difference in germination would not have been expected. In other (drier) years, the outcome might have been different.

An extension of the trial in the form of an addition of MBP and perhaps claying plots on the southern end of the trial should be considered for this year, to confirm some of the findings of last year.

Outcomes

Figure 1 illustrates the effect of non-wetting on crop establishment and yield.

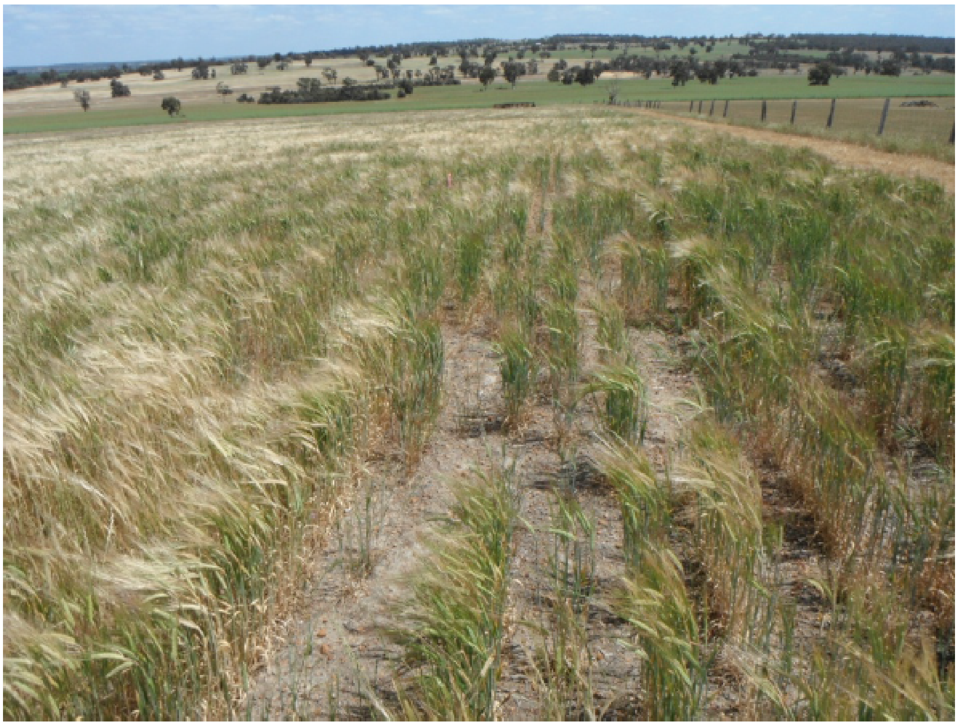

Figure 1. Gappy stand of barley in a severely non-wetting topsoil.

A number of mitigation and amelioration strategies for dealing with non-wetting soil have been proposed and are presented in Table 1.

Table 1. Summary of strategies for dealing with non-wetting soil (* indicates need for further evaluation).

Type	Management Option	Approximate Cost	Longevity	Suitable Soils	Mechanism
Mitigation	Improved furrow sowing	Cost of winged points or boots, press wheels	Short term, months	All repellent soils; forest gravels?*	Grading of repellent soil into ridges & water harvesting
	Banded wetting agent	$10- 12/ha/year;	Short term, months*	All repellent soils	Aids water penetration into furrow base
	Blanket wetting agent	$25-50 /ha/year depending on rate	Short term, 1-2 years*	Forest gravels*	Aids water penetration into topsoil
	Full stubble retention, low disturbance seeding	Possibly disc openers and more precise autosteer	Ongoing*		Water entry via remnant root pathways
Amelioration	Rotary spading	$150/ha	3-7 years*	All except rocky and stony soils	Soil dilution

Soil inversion (mouldboard plough)	$100-120/ha	Up to 10 years or more*	All except where shallow rock or clay is present	Inversion of wettable subsoil layer to the surface
Clay spreading and delving	$300-900/ha	More than 15 years	All except where shallow rock or clay is present (delving)	Higher soil surface area & clay content masks repellence

Background

Claying has been undertaken in many areas throughout the zone, and there is quite a bit of expertise on the risks and benefits associated with it within the zone. Cash flow of most growers in general does not allow the expense of high rates of clay to be used. However, there is anecdotal evidence to suggest that low rates of clay (lower than rates used currently to improve soil structure) will improve the wettability of the soil. By including clay in the trial, it is anticipated that the benefits of low rates of clay will show improved wettability.

Other opportunities for the zone appear to be mitigation of non-wetting, including on-row seeding. This would include associated practical risks around seeding such as stubble handling issues and accurate seeding systems. At different times, on-row seeding has shown a dramatic impact (see Figure 2).

Figure 2. Good and bad crop establishment by on-row (LH) and off-row seeding (RH) (top) and gappy stand by off-row seeding at harvest time (bottom).

Banded and blanket spray wetters are being used on many properties to help crop establishment. These products, in particular, could have a benefit in a dry seeding. While the mode of action is clear, the effectiveness of many of these products is, however, highly variable in the field. Including wetting agents in the trial will add to the body of knowledge that already exists about these products.

Mouldboard ploughing has been used successfully to improve non-wetting soils in the northern agricultural region of Western Australia (WA). Trial work has indicated that mouldboard ploughing can effectively remove water repellence. However, recent on-farm mouldboard ploughing that has been conducted in the southern coastal region has not been so successful. In some cases, wind erosion was a serious issue. The risk of bringing up shallow clay (sodic or non-sodic) that will hamper seeding and crop establishment should also be considered. By including this in the trial, mouldboard ploughing was investigated to see where and on which soil types this option would be realistic.

In addition to mouldboard ploughing, the use of a spader was also included. The spader is frequently used to incorporate heavy clay rates, or as a soil management option in its own right by mixing the topsoil with subsoil, and so diluting the non-wetting soil through a part of the profile.

Achievements/Benefits

Methodology

Location and soil type

The trial was located at Lloyd and Cheryl Burrell's property at Mt Madden, about 45km north west (NW) from Ravensthorpe, see Figure 3.

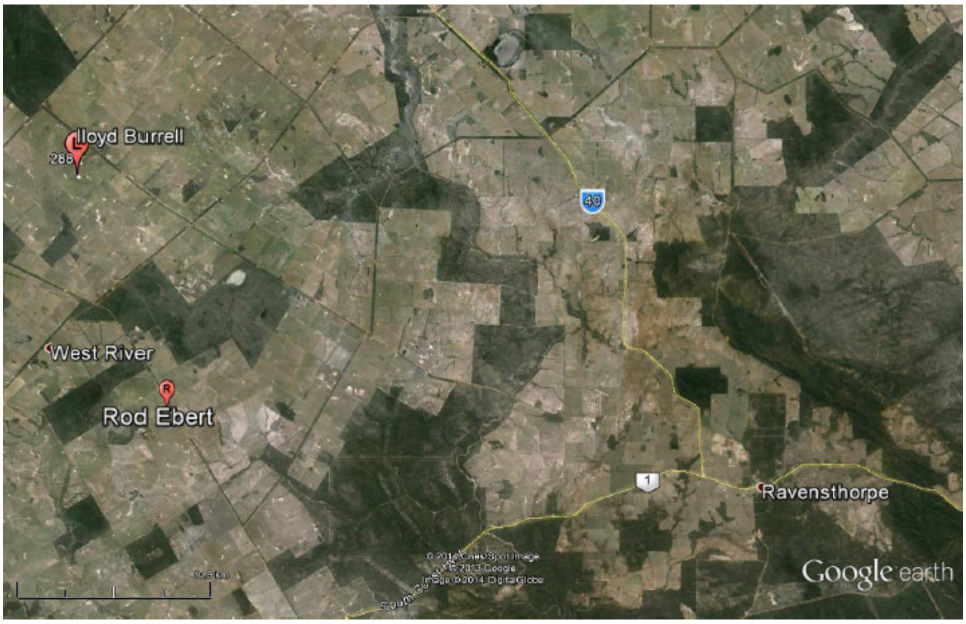

Figure 3. Location of trial site.

The soil type varies from a shallow loamy sandy gravelly duplex soil to a shallow clay duplex soil with moderate to severe non-wetting across the site. Non-wetting was measured in summer. In winter, the non-wetting disappeared in most areas, but remained severe in patches. According to the grower, the non-wetting has become gradually worse, hampering the evenness of crop and weed germination which in turn affects yield and effectiveness of herbicides. The topography of the paddock is basically flat with a gentle slope towards the north east (NE).

An overview of the general fertility of the paddock is presented in Table 2.

Table 2. Overview of the general fertility of the trial paddock at Burrell's site.

Location	NH3 (mg/kg)	NO (mg/kg)	P Colwell (mg/kg)	K Colwell (mg/kg)	S (mg/kg)	OC (%)	pH (CaCl2)	PBI
1	6	4	35	49	18.4	1.46	4.8	27
2	3	17	21	43	6.4	0.74	4.7	8
3	2	11	15	36	10.8	0.9	4.8	18
4	4	12	18	55	8.8	0.76	4.9	15
5	3	15	28	54	25.8	1.01	5	8
6	3	12	12	38	9.8	0.64	5.1	12
7	2	12	10	30	18.6	0.85	5.1	11

Table 3. Levels of soil pH ($CaCl_2$) taken from three different soil depths.The levels of Colwell P are quite variable, reflecting the changing soil type, as are the organic carbon (OC) percentages. The pH at the surface is good. Another survey of the paddock revealed, however, some low pH levels in the subsoil which need addressing (see Table 3).

Location	pH CaCl2 (0-10cm)	pH (CaCl2) (10-20cm)	pH (CaCl2) (20-30cm)
1	4.9	4.6	4.9
2	4.7	4.3	4.6
3	4.9	4.4	4.3
4	5.1	4.9	5.1
5	5.0	4.8	5.0
6	4.8	4.4	4.4

The treatments implemented in the trial were:

- Mouldboard ploughing (with and without spading). The spading was applied to one of the ploughed plots in an attempt to reduce the clod size brought up by the mouldboard plough in areas with shallow clay (see Figure 4). Ploughing was done with a Kverneland small three-furrow one-way plough operated on the three-point linkage. Ploughing on the 14th of February was only to a depth of approx. 20cm so as to reduce the amount of shallow clay brought to the surface (see Figure 4).

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Figure 4. Ploughing (left) and bringing up large clods of shallow clay (right).

- Spading on its own. A spader was used to dilute the non-wetting top soil by mixing it with the wettable subsoil down to a depth of approx. 20cm. Spading was done on the 8th of April, hence there was little time to break down any clay clods prior to seeding.
- Cultivation (i.e. scarifying) was carried out with a scarifier with large sweeps, in order to mix the topsoil with some subsoil creating a dilution effect.
- On-row, off-row and cross seeding. On-row seeding was achieved by nudging the tractor to a position that ensured as much as possible the positioning of the seeder bar right on top of the old seed rows. Off-row seeding was achieved in the same way but making sure that the seeder tynes were running in the inter-rows between the previous year's stubble rows. Cross seeding was achieved by seeding under a slight angle to the previous year's stubble rows.
- Claying (75t/ha and 125t/ha and Bentonite @ 8t/ha)) was achieved by scalping clay from an area in the vicinity of the trial site with a grader and loading the material in a top dresser with a front end loader. The rates were achieved after appropriately calibrating the topdressing application. The Bentonite was used as an alternative to the local clay. The use of Bentonite was trialled in 2012 near Darkan with some interesting results of higher yields, and a rapid increase in soil pH. The Bentonite has 36% clay (smectite), 26% ankerite and 29% calcite, the last two minerals being predominantly $CaCO_3$ minerals. The neutralising value of the Bentonite was 76% which explains the increase in soil pH. The Bentonite had, therefore, both a liming and a claying function. The claying was done on the 9th of April.
- Banded wetting agent at two different distances behind the press wheel (10cm and 20cm) at a rate of 2.5l/ha. The closer the application to the press wheel, the higher the chance that the wetting agent is covered by soil thrown up by the press wheel.
- Millet. This grower sometimes grows pearl millet (*Pennisetum glaucum*) (see Figure 5) to capitalise on summer rain.

Figure 5. Pearl millet in full flower.

The millet at the site was sown at the end of harvest the previous year (2012) after 88mm of rain in November, 2012. Little follow up rainfall eventuated though and the millet failed to set seed, and only a small amount of biomass was present at the time of seeding the trial. It was envisaged that the presence of millet trash and stubble would reduce the impact of non-wetting by reducing the soil surface evaporation over summer and stimulate soil biological activity which can improve the breakdown of the non-wetting organic compounds.

Rainfall and agronomy

Rainfall at the site was measured by a Department of Agriculture and Food WA (DAFWA) weather station located approx. 9km south east (SE) from the trial site. A summary of the rainfall is presented in Table 4.

Table 4. Actual monthly rainfall and growing season rainfall (GSR) at the DAFWA station.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	GSR (April-Oct)
Rainfall	56	6	75	5	55	25	44	52	85	59	13	37	325
Sum	56	61	137	141	196	222	266	318	403	462	474	511	

The monthly rainfall in the context of the long term rainfall is displayed in Figure 6. The long term rainfall from a station nearby (Cocanarup) was used; it was found that the rainfall measured at this station correlated well with the rainfall at DAFWA.

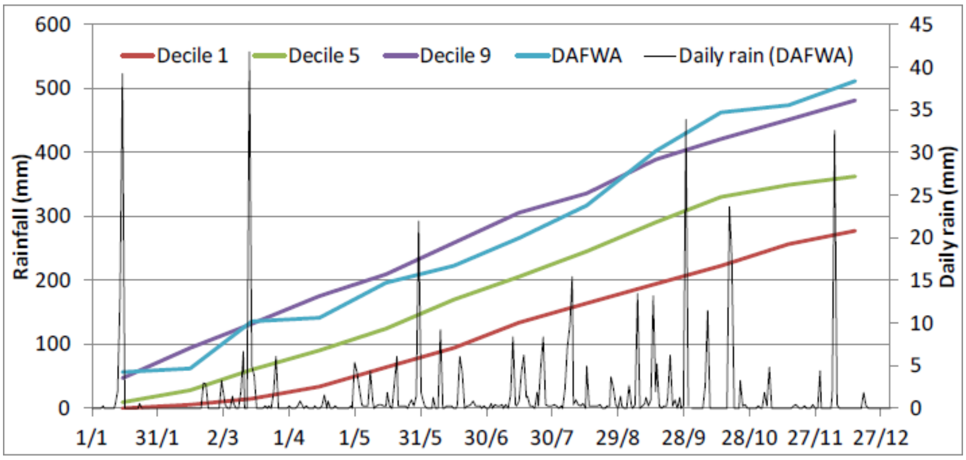


Figure 6. Daily and actual monthly rainfall (DAFWA) compared the long term Decile 1, 5 and 9 rainfall at Cocanarup.

From the Figure, it is clear that the actual rainfall in 2013 was close to and even exceeded the Decile 9 rainfall, which made it a wet year and not amenable to displaying non-wetting symptoms. In particular, the wet start to the season in January and March enabled a rapid breakdown of the non-wetting properties.

The crop, barley Gairdner, was sown on the 30th of April together with 80kg/ha of Agflow and 40l/ha of FlexiN in strips that were 200m long and 12m wide, the width of the seeder bar and the harvester. Other actions of crop husbandry were carried out as required during the season.

The layout of the trial followed the South East Premium Wheat Growers Association (SEPWA) trial setup, in which two treatments are adjacent to a control. The multiple controls will give an indication of any spatial trends. The lack of replicates, however, in the treatments in this setup can make result interpretation difficult.

Results

Crop germination and soil moisture

The number of plants per m^2 were counted 22 days after seeding. At the same time the soil moisture at a depth of 2cm and at 5cm was measured with a moisture meter (WET sensor, Delta-T devices). In the control plots, these measurements were done in the seed furrow, as well as in the old stubble row. The results are presented in Figure 7.

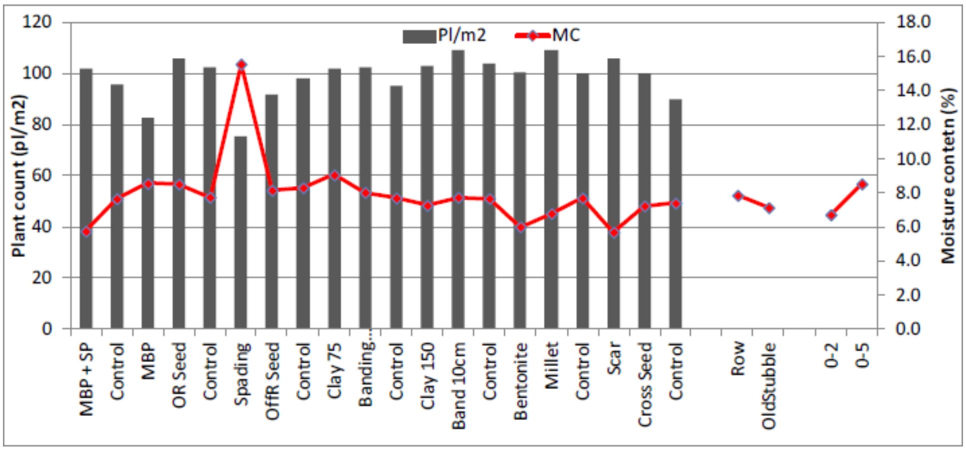


Figure 7. Plant count and soil moisture taken 22 days after seeding.

Plant numbers in the MBP and the spading plots were down compared to the rest due to poor establishment on the cloddy areas (see Figure 8). Too little time had lapsed, particularly in the spaded plot, to break down the large clods brought up in areas with shallow clay to make a nice crumbly seed bed. An application of gypsum topdressed over the clods would have possibly assisted in that process.

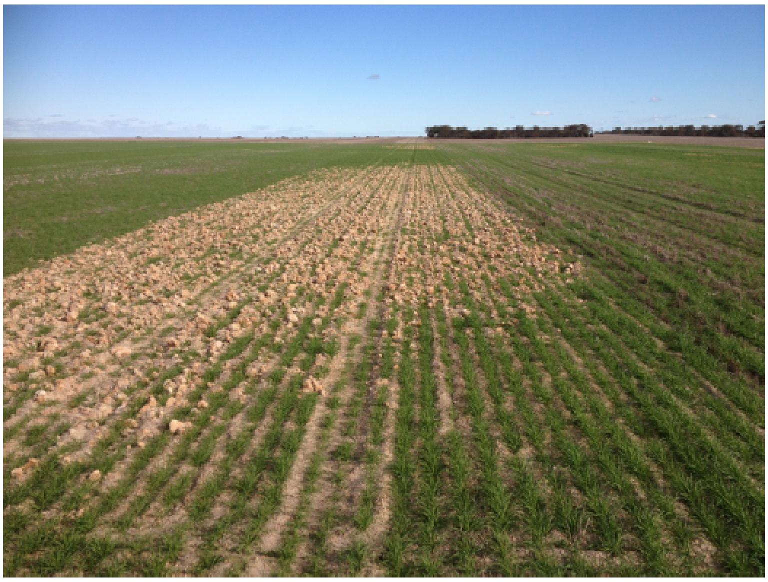


Figure 8. Poor crop establishment in cloddy areas on the 17th of June.

Soil moisture on the 22nd of May trended downwards to the right (or the southern end of the trial) where the soil becomes more non-wetting and more gravelly. The exception was the spading plot where large amounts of clay at the surface raised soil moisture but did not improve establishment.

There was no significant difference between soil moisture in the seed row and the old stubble as is sometimes the case (Fig. 7). This creates the difference between on- and off-row sowing but it is not effective every year. The soil moisture content at 2-5cm was slightly higher than at 0-2cm as was expected.

Subsequent soil moisture measurements on the 30th of July and the 28th of August did not follow the 22 May trend (see Figure 9); if anything the trend was slightly reversed.

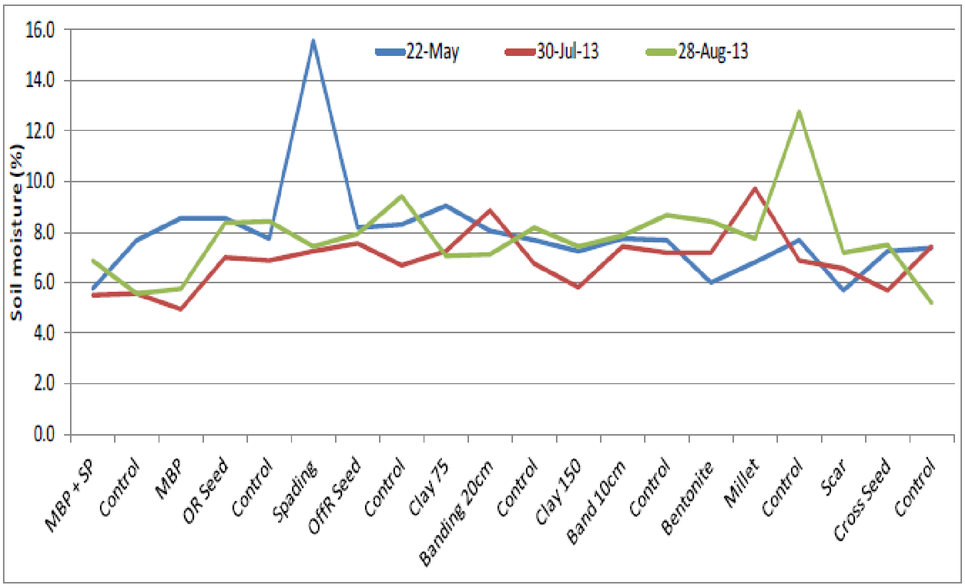


Figure 9. Soil moisture transect on three different dates.

The plots on the left (northern side of the trial) were slightly drier which could be explained by the larger crop grown on that part of the trial.

<u>Normalised Difference Vegetation Index (NDVI)</u>

Twice during the season the biomass was measured with a GreenSeeker™. This instrument measures the reflected red and near infra red (NIR) light from the surface that has been illuminated with red and NIR light by the unit. The amount of reflected light is inversely proportional to the amount of green matter on the surface and is used to calculate the NDVI, which usually ranges from 0.15 (bare ground) to 0.9 (a solid green canopy). The GreenSeeker™ was mounted on the front of an all terrain vehicle (ATV) (see Figure 10). Three runs were made in each plot in a wavy pattern. The NDVI and the position of the

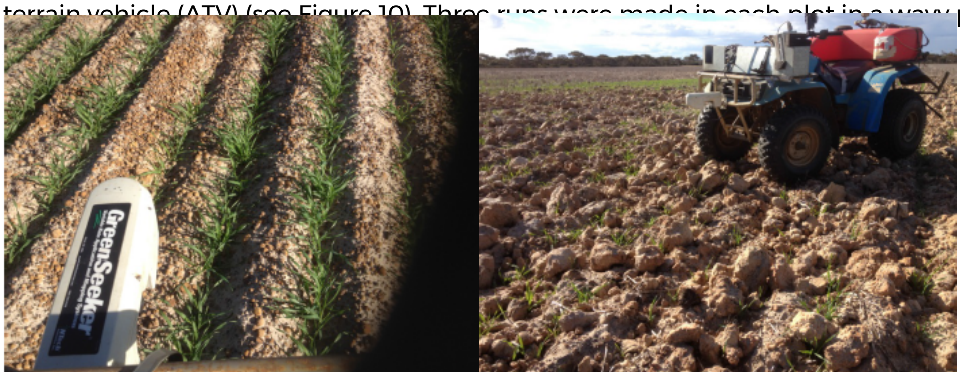


Figure 10. Crop canopy (NDVI = 0.25) (left) and the poor germination in the cloddy areas (NDVI = 0.15).

From the measurement, the average NDVI of each plot was calculated and is presented in Table 5.

Table 5. Mean NDVI of each plot and the significance. The same letter means no significance (5%).

Treatment	Mean NDVI 27th May	Sig.	Treatment	Mean NDVI 25th July	Sig.
MBP + SP	0.18	a	Spading	0.56	a

Spading	0.19	a	Cross Seed	0.60	ab
MBP	0.19	a	OR Seed	0.60	ab
OR Seed	0.23	ab	Clay 75	0.63	ab
OffR Seed	0.24	ab	MBP	0.63	ab
Cross Seed	0.26	ab	OffR Seed	0.64	ab
Clay 75	0.26	ab	Control	0.65	b
Control	0.27	b	Bentonite	0.65	ab
Clay 150	0.27	ab	Scar	0.65	ab
Banding 20cm	0.29	b	Clay 150	0.67	b
Scar	0.29	b	Millet	0.67	b
Banding 10cm	0.29	b	Banding 20cm	0.70	b
Bentonite	0.30	b	MBP + SP	0.70	b
Millet	0.30	b	Banding 10cm	0.70	b

The MBP and spading treatments performed very poorly in May but improved in July, except for the spading. None of the treatments stood out as doing much better than the control and there was no evidence of a general trend. The NDVI values are presented spatially in Figure 11.

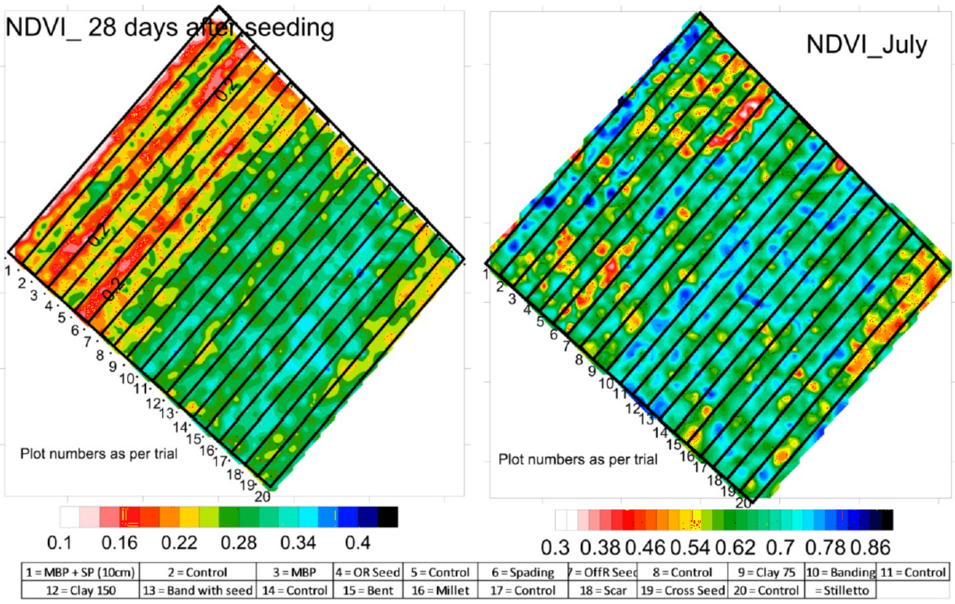


Figure 11. Distribution of the NDVI across the trial area and within each plot on two different dates.

In certain plots such as 5, 6 and 20, the patchy nature of the crop is clearly evident. Towards the southern part of the trial, the soil becomes more non-wetting and it is very likely that the patchiness is caused by that, even in a wet year such as 2013.

On the 29th of October, an aerial photo was taken from the trial site which is presented in Figure 12.

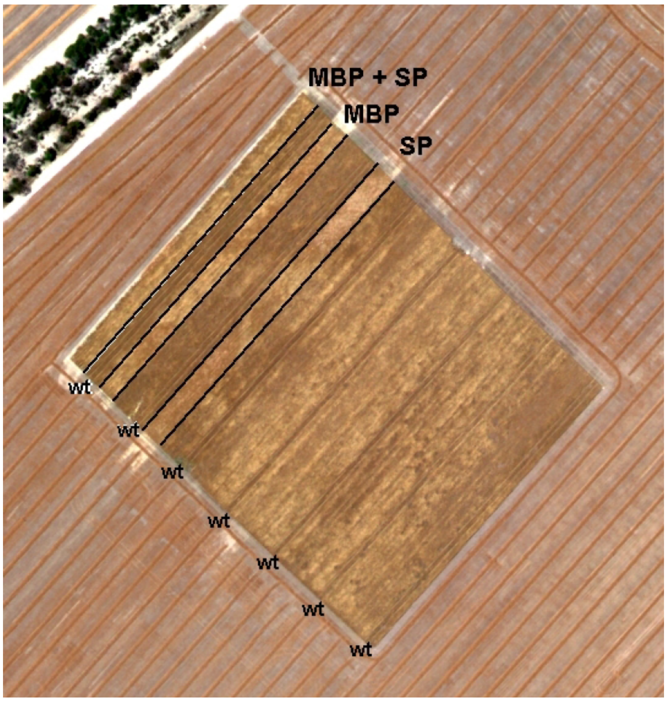


Figure 12. Aerial image of the trial site taken on the 29th of October.

Differences in the canopy can be seen since the northern part of the trial is considerably darker than the southern part. In addition, the wheel tracks at a distance of 36m can be clearly seen. These wheel tracks ended up in every control plot which would have disadvantaged the productivity in those plots. If it is assumed that the wheel tracks are 50cm wide x 2 = 1.0m in total. For a plot width of 12m that constitutes 8.3% of the area is taken up by wheel tracks. If the yield in the wheel tracks is only 30% of the normal yield, the whole yield of the control plots would be depressed by 5.8% (0.83 x 0.7) due to the presence of the wheel tracks. This should be taken into account when looking at the yield results.

<u>Yield</u>

The trial was harvested on the 13th of November. The grain was taken from each plot using a commercial harvester header and weighed in a small weigh bin and the yield (t/ha) calculated. There was a strong spatial trend as is shown in Figure 13. This can be allowed for in the statistical analysis of the data by including a factor reflecting the spatial location of each plot. The weight of each plot is then adjusted for this spatial trend and the analysis done based on the adjusted means of the yield.

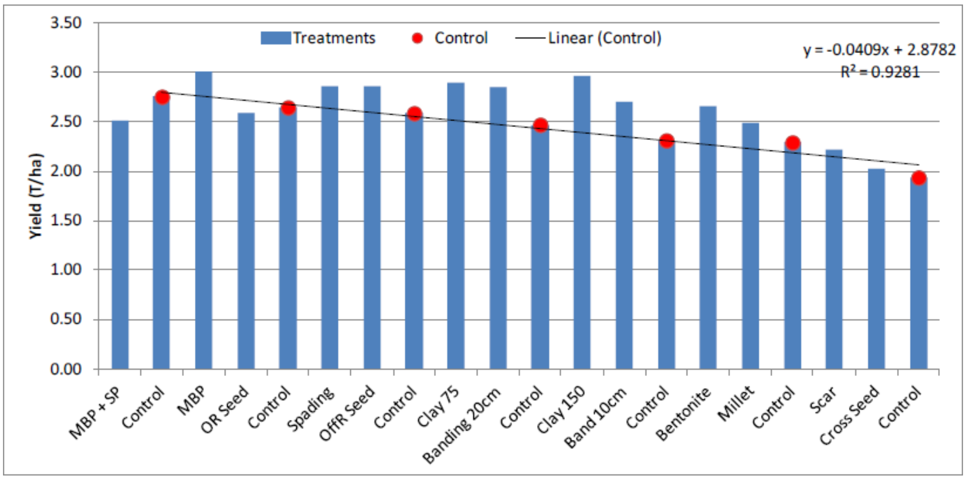


Figure 13. Yield of each plot and the spatial trend. After adjusting for the spatial trend, the results are presented in Table 6.

Table 6. Adjusted and measured mean of the grain yield of each plot.

Treatment	Adjusted Mean	Sig.	Treatment	Measured Mean	Sig.
MBP + SP	2.12	a	Scar	2.03	a
OR Seed	2.33	ab	Cross Seed	2.22	ab
Scar	2.38	abc	Control	2.43	ab
Control	2.45	bc	Bentonite	2.48	ab
Cross Seed	2.53	bcd	MBP + SP	2.51	ab
Spading	2.68	cd	OR Seed	2.59	ab
MBP	2.70	d	Millit	2.65	ab
Bentonite	2.71	d	Banding 20cm	2.71	ab
OffR Seed	2.72	de	Banding 10cm	2.85	ab
Banding 20cm	2.81	de	OffR Seed	2.87	ab
Banding 10cm	2.83	de	Spading	2.87	ab
Millit	2.84	de	Clay 75	2.90	ab
Clay 75	2.84	de	Clay 150	2.97	ab
Clay 150	3.03	e	MBP	3.01	b

The highest measured yield came from the MBP (3.01t/ha) while the scarified plot yielded the lowest. The measured yield from the clayed plots was also very good but none of the yields were significantly different except the highest and the lowest. Allowing for the spatial trend, the results became much more significant. The clayed plots were now the best while the MBP + SP became the worst. There is little evidence yet that the added clay made much difference to the non-wetting soil properties, but its ability to hold onto the moisture and nutrients might have given the clayed plots an increase in yield. Both the clayed plots were in the middle of the trial site perhaps benefiting from a better soil type but not penalised for the location, as was the case with the MBP + SP plot. This is one drawback of this type of trial layout with no replicates in the treatments.

Compared to the control, the clayed plots yielded significantly more by approx. 0.5t/ha which equates to about $150 for an investment of at least $300/ha. Obviously the claying is expected to be effective for many years and it will be interesting to see how the plots will yield in subsequent years.

The grain quality was also measured with an average of 9.4%, 13.5%, and 56% for the protein, the moisture and the colour, respectively. There was a strong trend in the screenings (Fig. 14) and, therefore, the hectoliter weight (Fig. 15). The first trend would reflect the soil type as the season finished rapidly with little rainfall in November, and the screenings increased in the shallow gravelly non-wetting soil type.

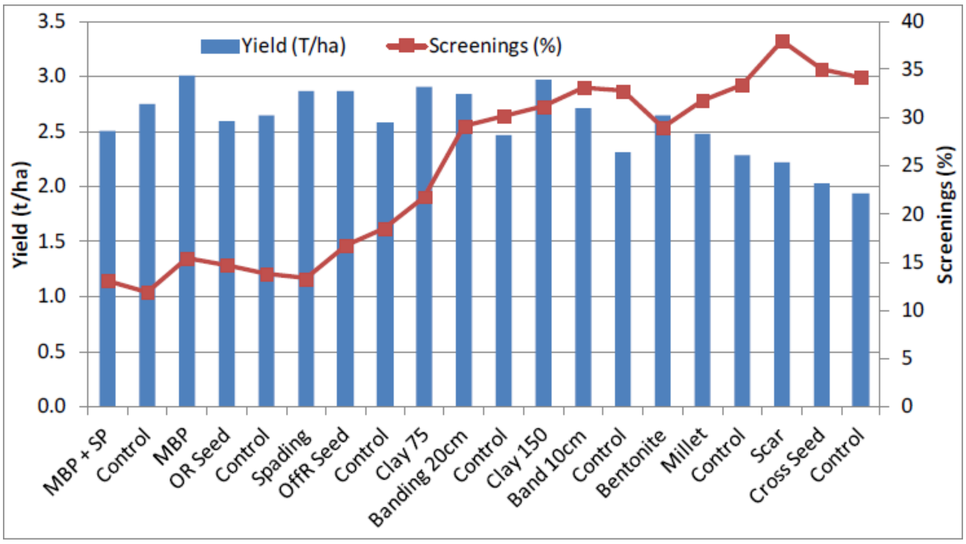


Figure 14. Trend of the yield and the screenings across the trial site.

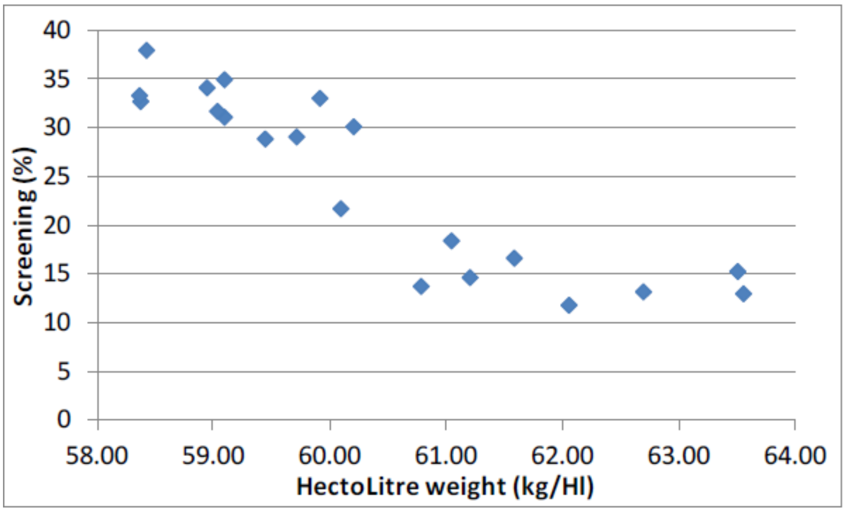


Figure 15. Relationship between the hectolitre weight and the screenings.

Based on these screening figures, half of the trial area would have become feed barley while the other half would have been malt.

Farmanco economic analysis of trials at L. Burrell and R. Ebert

<u>Summary</u>

1. These are the pre-cursor trials for a series of trials over four years.
2. The two trials test a number of theories.
3. There were very large yield differences in both trials:
   Burrell 2.45t/ha to 3.03t/ha (0.5t/ha); Ebert 2.69t/ha to 4.23t/ha (1.5t/ha).
4. The trials present significant financial benefits of mouldboarding, wetters and spading, but also some clear warning signs for use of these options, in some conditions.
5. The trials raise more questions than answers and some of these will be explored in future trials.
6. These trials need to be considered in conjunction with each other.
7. One of the outcomes is to start building a cost base for alternatives such as claying, spading, etc for future use of RAIN members.

<u>Benefits</u>

1. The Ebert trial shows clear economic benefit for mouldboarding (+$419/ha) or spading (+$228/ha).
2. Claying and wetters did not provide a significant or consistent economic advantage at the Ebert site.
3. The Burrell trial shows a clear economic benefit for use of wetter, inter-row seeding and claying and spading.
4. The yield benefits of claying and spading tended to be offset by the costs.

Warnings

1. The Burrell trial showed that mouldboarding of 'domed' soils brought the hard domes to the surface like large hard clay rocks. This will provide a couple of years of rolling to crush these domes. The impact on reduced seed-soil contact and management are potentially significant.
2. Care needs to be taken with the use of mouldboarding which can be very beneficial (Ebert) but not if dig up domes (Burrell).
3. This was a very unusual year for a non-wetting trial - very wet (see Figure 6). This may well have exacerbated the differences between the outcomes.

Future Considerations

1. Consideration of electromagnetic surveys to determine depth to domes. This might enable the ability to consider mouldboard ploughing on some soil types without bringing 'domes' to the surface.
2. Interactions in conjunction with lime and/or gypsum with these techniques. A gypsum half of the trial is being considered at the 'Duncan' trial site in 2014.

Other Questions Raised

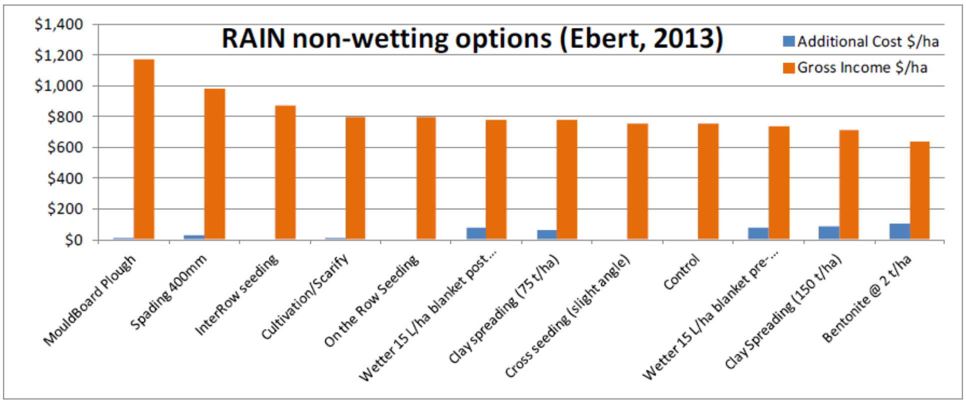
1. Why have wetters showed such a good result on the Burrell site? Even though the seeding was wet, there can be impacts from non-wetting soils. However, there did not seem to be a significant difference in plant establishment per square metre. This does not give a good reason as to why the wetters have worked so well. Some more investigation is required.
2. In the same trial, inter-row seeding (at no additional cost) showed a significant benefit over the control and on-the-row seeding. Given good establishment conditions, there are only two reasons to explain this: a) sowing on-the-row provided too wet an environment and b) inter-row sowing has reduced disease impacts. However, neither of these 'appeared' to be able to explain such a large difference.

Results

Ebert

EBERT Treatment	Mean Yield t/ha	No Adjust Required	Gross($/ha) 280 /t	Additional Cost	Income Less Costs	Marginal Difference	Payback Period (yrs)
MouldBoard Plough	4.23	4.23	$1,184	$12	$1,172		
Spading 400mm	3.61	3.61	$1,011	$30	$981	$192	10
InterRow seeding	3.10	3.10	$868		$868	$113	
Cultivation/Scarify	2.87	2.87	$804	$10	$794	$74	
On the Row Seeding	2.83	2.83	$792		$792	$1	
Wetter 15 L/ha blanket post seeding	3.06	3.06	$857	$75	$782	$11	10
Clay spreading (75 t/ha)	3.00	3.00	$840	$60	$780	$2	

Cross seeding (slight angle)	2.70	2.70	$756		$756	$24	
Control	2.69	2.69	$753		$753	$3	
Wetter 15 L/ha blanket pre-seeding	2.90	2.90	$812	$75	$737	$16	
Clay Spreading (150 t/ha)	2.85	2.85	$798	$84	$714	$23	10
Bentonite @ 2 t/ha	2.62	2.62	$734	$100	$634	$80	10



Discussion

The differences in this trial are very significant.

It is clear that this soil has responded well to mouldboard ploughing above all other options. The analysis takes into account the cost of mouldboarding and spreads this cost over ten years. However, this result would clearly pay for this activity in one year.

This was a very high yielding year, and it is not known how repetitive the yield is likely to be, but a one year payback is very significant.

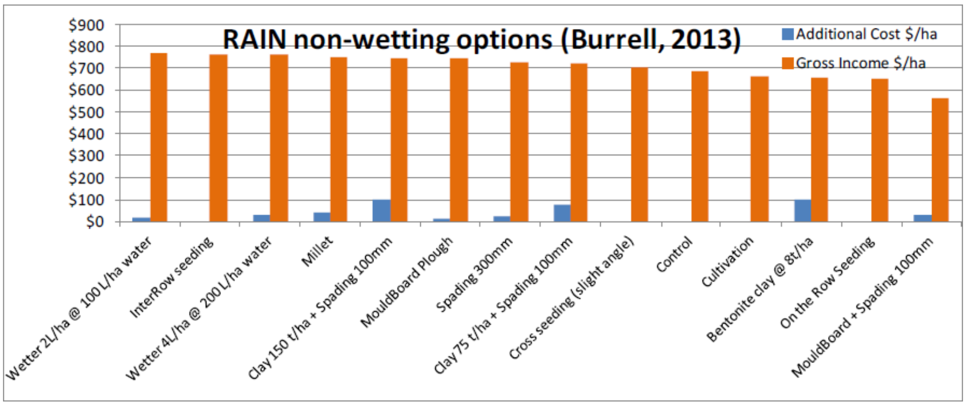
Spading on this site was also significant. The question is raised that if there is a choice between mouldboarding and spading, would the full inversion of soil be better in terms of the benefit of weed control which may well have been part of the benefit shown in this trial.

It is important to note that inter-row seeding was significantly better than the control in both trials. This is potentially a relatively low cost to adapt to for businesses on autosteer with 2cm accuracy.

Burrell

Lloyd Burrell Treatment	Mean Yield t/ha	Adj Yield t/ha	Gross ($/ha) 280 /t	Additional Cost	Income Less Costs	Marginal Difference	Payback Period (yrs)
Wetter 2L/ha @ 100 L/ha water	2.71	2.81	$787	$20	$767		
Inter-row seeding	2.87	2.72	$763		$763	$4	

Wetter 4L/ha @ 200 L/ha water	2.85	2.83	$791	$30	$761	$2	
Millet	2.65	2.84	$795	$40	$755	$6	
Clay 150 t/ha + Spading 100mm	2.97	3.03	$848	$99	$749	$6	10
Mouldboard Plough	3.01	2.70	$757	$12	$745	$4	10
Spading 300mm	2.87	2.68	$751	$25	$726	$18	10
Clay 75 t/ha + Spading 100mm	2.90	2.84	$795	$75	$720	$6	10
Cross seeding (slight angle)	2.22	2.53	$708		$708	$12	
Control	2.43	2.45	$686		$686	$22	
Cultivation	2.03	2.38	$666		$666	$20	
Bentonite clay @ 8t/ha	2.48	2.71	$758	$100	$658	$7	10
On the Row Seeding	2.59	2.33	$651		$651	$7	
Mouldboard + Spading 100mm	2.51	2.12	$594	$27	$567	$85	10



Discussion

Note that the yields in this site were adjusted according to the regular control strips due to yield variation across the site.

It is clear that wetters have had a large impact in this trial. This is difficult to explain as previously discussed but needs more consideration, particularly in marginal soil moisture conditions.

It is noted that inter-row seeding was once again significant.

Interestingly, the mouldboard ploughing did have a positive result on yields. This is surprising given the large lumps of clay that were brought to the surface. This is most likely due to ideal seeding conditions, enabling good establishment, but does suggest that yields can be improved despite this clear impediment.

The millet option was included because there was anecdotal evidence that yields on non-wetting soils can be improved following a summer millet crop. This has proved to be significantly better than the control. However, this result is likely to vary significantly depending upon summer moisture conditions. The theory is that the deep rooted summer crop establishes pathways for the winter crop to follow. This could be a good option for businesses with livestock but might also have the difficulty of reducing moisture available to winter crops in below average rainfall years.

Cost Assumptions

Some of the following costs have not been based on actual cost of work completed in this location. To this end, some assumptions have been made, and reliance on these costs will not be useful without further investigation relating to a particular location or availability of contract services.

$840

$84

Claying	Clay Rate (t)	350	300	200	150	100	75 t/ha
	Cost to Spread	$1,000	$900	$800	$700	$600	$500 $/ha
	Incorp/Smudge	$180	$180	$180	$140	$120	$100 $/ha
	Total Cost/ha	$1,180	$1,080	$980		$720	$600 $/ha
	Repay Period 10	$118	$108	$98		$72	$60 /ha/yr

Mouldboarding	Cost/ha	120 /ha
	Longevity 10 Yrs	12 /ha/yr

$250

Spading	Depth	400mm	300mm	200mm	100mm
1ha/hr at 400mm depth	Cost/ha	$300		$200	$150 /ha

$300/hr	Repay Period 10	$30	$25	$20	$15 /ha/yr

Bentonite Clay	Cost/ha Est	$1,000 /ha
	Repay Period 10	$100 /ha/yr

Mouldboard + Spading 100mm	$27 /ha	
Clay Spreading 75t Spading 100mm	$75 /ha	As per costs outlined above
Clay Spreading 150t Spading 100mm	$99 /ha	As per costs outlined above
Millet	$40 /ha	Seed + Seeding Cost + No fertiliser
Wetter 2l @ 100/ha	$20 /ha	Wetter $10/ha ($5/L)+ Setup costs on bar $10/ha
Wetter 4l @ 200l/ha	$30 /ha	Wetter $20/ha ($5/L)+ Setup costs on bar $10/ha

Additional information

Acknowledgement

The assistance of Grey Poulish (DAFWA Albany) in data collection is greatly appreciated as well as the assistance of neighbouring growers in making machinery available.

Extension Work

March 8th 2013: 2013 Ravensthorpe Agricultural Initiative Network (RAIN) Crop Updates — 62 attendees (46 growers, 16 agribusiness)

September 17th 2013: West Ravensthorpe Spring Field Day — Ebert's Property - 78 attendees. Also presenting were David Hall (DAFWA) and Phil Ward (CSIRO.)

March 2014: RAIN Crop Updates - trial results were presented in the Crop Updates booklet - 71 attendees

Numerous articles in local paper.