GRDC Regional Cropping Solutions Network Final Report

Project: DAW00254 Furrow Formation and Inter-row Compaction (FFIC) for improved wheat production in water-limited environments of the wheatbelt of WA

Introduction:

Through Mr. Callum Wesley's preliminary trials earlier and in the 2013 season, it is understood that the Furrow Formation Inter-row Compaction (FFIC) technology (patent pending Wesley Wheels) increases water harvesting thereby increasing crop production under low rainfall conditions.

Prototype inter-row compaction wheels were shown at the Merredin Research Station field day in 2013. More wheels were made with four row spacings to fit a cone seeder from Geraldton in 2014, and a site at Merredin Research Facility and Southern Cross was sown to wheat. Water harvesting was apparent from soil moisture profiles and measurements (Figures 1 and 2 and Table 1).

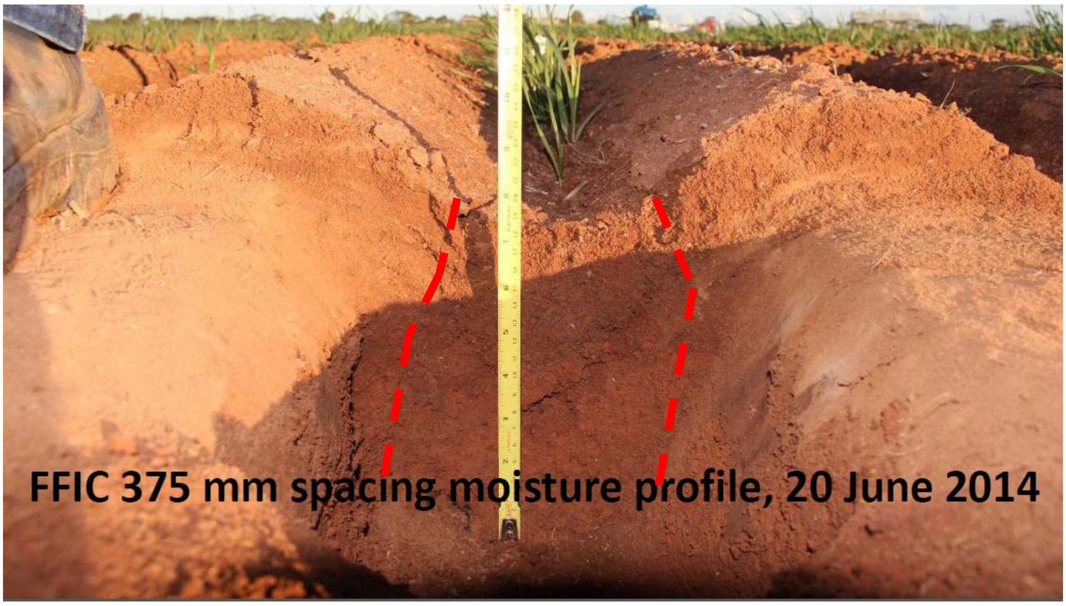
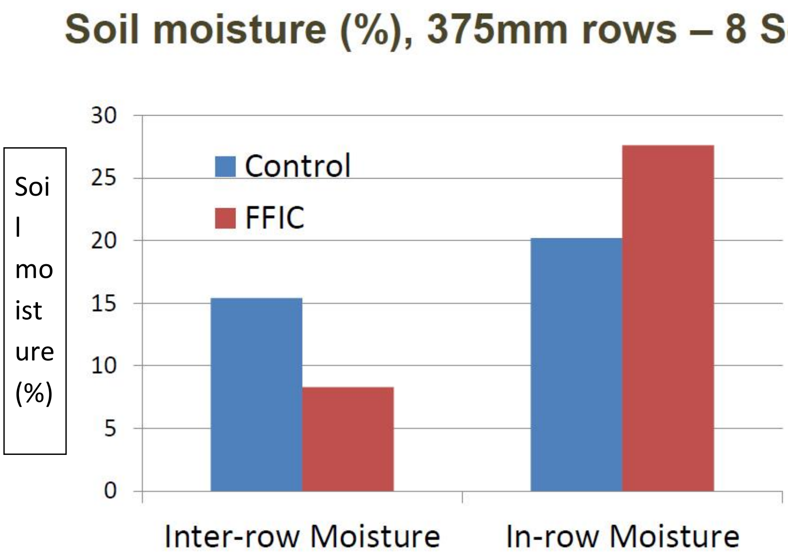


Figure 1. Soil moisture profile with Wesley Wheels at 375mm row spacing in 2014 at Merredin. Between the red dashed line indicates the wet in-row soil profile.



Picture 25 Sept

Figure 2. Volumetric soil moisture from inter-row and in-row at Merredin 8 September 2014. The control is conventional sowing with knife points and press wheels.

Table 1. Volumetric soil moisture with treatment at Merredin 8 Sept 2014.

Treatment	Inter-row moisture (%)*	In-row moisture (%)*
Control or conventional 375 mm spacing	15.4 a	20.2 a
FFIC 375 mm spacing	8.3 b	27.6 b
Lsd	1.8	5.71
F pr	0.001	0.026
Coefficient of variation	6.6%	10.6%

* Similar letters after the number are not significantly different at the 5% level.

Objectives:

To test the effect of compacted inter-rows on water harvesting, production and profitability in a low rainfall wheatbelt environment.

Trial Locations:

Merredin: 31.488017 S, 118.230399 E Southern Cross: 31.185422 S, 119.369437 E

Methodology:

In addition to the above Objective, Dr Paul Blackwell (DAFWA) suggested to also test if water harvesting could be achieved on alternate rows thereby having inter-row soil water available later in the season for grain fill.

There are two means to validate the Wesley Wheel concept. (1) Measuring grain yields on compacted inter-rows and Control (level field) plots in multi-locational trials is the ultimate test. However, (2) the effects of these treatments on increasing soil water to crops are also critical to optimising treatments (row spacing, furrow depth etc) and the interpretation of results.

Unfortunately the 2015 the trial plan was put on hold around seeding time due to the GRDC contract with DAFWA not being signed. This was not resolved in time so the Mullewa site was abandoned and the Merredin and Southern Cross trials were done later than originally planned.

The Merredin site was sown in 2014 to wheat but had a large amount of crown rot so the site was sown to canola (as part of a crop rotation) in 2015.

Treatments:

1. Control 300 mm row spacing (C300)
2. Control 375 mm row spacing (C375)
3. Control 460 mm row spacing (C460)
4. Furrow formation inter-row compaction 300 mm row spacing (FFIC300)
5. Furrow formation inter-row compaction 375 mm row spacing (FFIC375)
6. Furrow formation inter-row compaction 460 mm row spacing (FFIC460)
7. Control 300 mm but alternate sown row spacing (effectively 600mm C300A)
8. Furrow formation inter-row compaction 300mm but alternate sown rows (FFIC300A)

The Southern Cross site was sown to wheat in 2014 and was again sown to wheat in 2015. A product called Zeba is promoted as a water holding compound similar to gel crystals used in pot plants so this was tested at two rates added with the seed at Southern Cross in 2015.

Southern Cross treatments:

1. Control 300 mm row spacing
2. FFIC 300 mm row spacing
3. Control 375 mm row spacing
4. FFIC 460 mm row spacing
5. Control 460 row spacing
6. FFIC 460 mm row spacing
7. FFIC Zeba 2.0 kg/ha 375 mm row spacing
8. FFIC Zeba 4.0 kg/ha 375 mm row spacing

Experimental Design: Randomised block with four replications at both sites.

Results:

1. Merredin trial results:

Forming date:	22 April 2014 on dry soil and then later sown to wheat
Row orientation:	21 degrees west of north
Plot size:	2.5 x 20m, 7 rows at 300mm, 6 rows at 375mm, 5 rows at 460mm
Trial design:	Randomised block with 4 replicates
Seed Date:	14 May 2015 and all plots sown north to south
Seed Rate:	1.634 kg/ha new Bonito canola (pickled with Cruser + Maximal) seed weight 3.814 g/1000
Viable seed sown:	43 seeds/m^2
Fertiliser:	50 kg/ha Agras (16.1%N, 9.1%P, 14.3%S, 0.5%Ca, 0.06%Zn) 3 cm below the seed, based on soil tests (table 2).
Seeder:	Points 50mm wide steel, chamfered "V" Agmaster press wheels set at 4 kg/cm width (probably should have been 2 kg/cm).
Sprays:	14/5/15 – 2 L/ha Spray.Seed + 1.5 L/ha trifluralin + 1.1 kg/ha atrazine
Harvester:	KEW 1.6m wide (two cuts per plot)
Harvest date:	3 Nov 2015.

Table 2. Merredin CSBP soil test results taken on 15 April 2014:

Depth	0 – 5 cm	5 – 10 cm	10 – 15 cm	Average 0 – 15 cm
pH (1:5 $CaCl_2$)	***4.6****	***4.8***	***5.4***	***4.93***
EC (1:5 dS/m)	0.173	0.146	0.067	0.129
Org C % (W&B)	1.02	***0.75***	***0.53***	***0.767***
NO_3-N (mg/kg)	55.3	41.7	***12.8***	36.6
NH_4-N (mg/kg)	23.7	16.1	***3.1***	14.3
P (Colwell mg/kg)	54	32	***18***	34.7
PBI + ColP	43	46	58	49
K (Colwell mg/kg)	382	327	267	325
S (KCl 40 mg/kg)	25	22	9	18.7
Soil stability	low	low	marginal	low
Ca – exch (cmol/kg)	***3.57***	***4.42***	6.48	4.82
Mg – exch (cmol/kg)	1.73	2.4	4.06	2.73
K – exch (cmol/kg)	0.98	0.84	0.69	0.84
Na – exch	0.54	0.61	1.07	0.74

(cmol/kg)				
Al – exch (cmol/kg)	0.19	***0.09***	***0.10***	0.127
Cu (DTPA mg/kg)	0.9	0.9	0.9	0.9
Zn (DTPA mg/kg)	0.6	0.5	0.3	0.47
Mn (DTPA mg/kg)	55	43	24	40.7
Fe (DTPA mg/kg)	36	23	14	24.3
B ($CaCl_2$ mg/kg)	1.7	1.8	2.1	1.87
Cl (1:5 mg/kg)	63	34	25	40.7
Al ($CaCl_2$ mg/kg)	0.6	0.3	0.2	0.37

* Bold and Italics are marginal on the CSBP results printout

A target yield of 2 t/ha was chosen and the CSBP recommended rate of 50 kg/ha of Agras fertiliser (16.1%N, 9.1%P, 14.3%S, 0.5%Ca, 0.06%Zn) was used. The pH was marginal as was the organic carbon (See Table 1 for soil analyses.).

Extra treatments were included in 2015 from buffer plots from 2014 but only plots set up in 2014 are included in this analysis. The plant density was much lower for all the furrow formation treatments which was most likely due to sowing too deep (Table 2). Setting the depth is always difficult with machine changes and canola is very sensitive to sowing depth, particularly on heavy clay loam soil as used here.

There was a fair variation in plant number within plots as well which is reflected in the relatively high coefficient of variation of 22% (try to be less than 15% for field trials). The yield was variable with the Control 460mm higher than all but the Control 300mm (Table 3). A large rain event in March may have reduced the potential impact of water harvesting with the wheels as the soil water profile would have been more full than normal at the start of the season.

Table 3. Canola plant density and yield with treatment at Merredin.

Treatment	Plant density* (pl/m^2)	Yield* (t/ha)
1. Control 300 mm spacing	19.1 a	0.814 ab
2. Control 375 mm spacing	19.7 a	0.752 bc
3. Control 460 mm spacing	19.6 a	0.853 a
4. Furrow formation 300 mm spacing	12.8 b	0.737 c
5. Furrow formation 375 mm spacing	12.3 b	0.769 bc
6. Furrow formation 460 mm spacing	7.0 c	0.750 bc
7. Control 300mm alternate	16.2 ab	0.778 bc
8. Furrow formation 300 mm alternate	7.1 c	0.763 bc
Lsd ($p<0.05$)	4.6	0.0714
F pr	<0.001	<0.001
Coefficient of variation (%)	22.0	6.2

* Similar letters after the number are not significantly different at the 5% level.

There were no significant differences in seed quality or seed weight with treatment, which may have been due to the very dry September (Table 4).

Table 4. Merredin Rainfall (2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2015	0.0	0.4	74.0	20.8	12.8	35.4	104.4	43.0	5.4	10.4	31.4	6.6	344.6
Long term Mean	14.6	15.4	20.3	22.9	40.9	49.1	50.5	38.5	25.9	18.5	14.7	14.1	325.4
Long term Median	6.1	6.1	10.9	16.5	33.4	46.0	45.0	38.5	22.4	12.8	8.8	5.4	307.0

2. Discussion of Merredin Results:

It was interesting that the wider alternate sown rows (treatments 7 and 8, effectively 600mm) had similar yields to other treatments. Perhaps the dry September allowed the wide rows to tap into the inter-row soil water. It was noticed that treatments 7 and 8 had taller plants than the other treatments (Figure 3).

The Merredin trial had emergence problems that probably affected yields. The control 300mm and 460mm yielded higher than other treatments, which may have stemmed from the better emergence. The 600mm row spacing treatments yielded reasonably well, possibly due to the very dry spring.

Figure 3. Harvesting rep 1 on 3 November 2015; note the taller 600mm wide rows in the background (inside red box).

3. Southern Cross trial results:

Forming date:	2014 but reformed 11 June 2015 on relatively dry soil
Row orientation:	North-South
Plot size:	2.5 x 20m, 7 rows at 300mm, 6 rows at 375mm, 5 rows at 460mm
Trial design:	Randomised block with 4 replicates
Seed Date:	11-12 June 2015 and all plots sown north to south (Figure 4)
Seed Rate:	40 kg/ha Zippy wheat
Viable seed sown:	90 seeds/m^2
Fertiliser:	70 kg/ha Agras (16.1%N, 9.1%P, 14.3%S, 0.5%Ca, 0.06%Zn) 3 cm below the seed, based on soil test results (table 5).

Seeder:	Points 50mm wide steel, chamfered "V" Agmaster press wheels set at 4 kg/cm width.
Sprays:	12/6/15 2.0 L/ha Spray.Seed for clover, self-sown wheat and doublegee.
Harvester:	KEW 1.6m wide (two cuts per plot).
Harvest date:	18 Nov 2015

Figure 4. Reforming 460mm rows with Wesley wheels at Southern Cross before sowing on 12 June.

Table 5. Southern Cross CSBP soil test results taken on 13 April 2014:

Depth	0 – 5 cm	5 – 10 cm	10 – 15 cm	Average 0 – 15 cm
pH (1:5 $CaCl_2$)	***5.5****	5.8	5.8	5.70
EC (1:5 dS/m)	0.048	0.064	0.070	0.061
Org C % (W&B)	***0.83***	***0.80***	***0.57***	***0.73***
NO_3-N (mg/kg)	16.6	21.2	29.6	22.5
NH_4-N (mg/kg)	5.2	1.4	1.3	2.63
P (Colwell mg/kg)	***19***	***12***	***8***	***13.0***
PBI + ColP	49	50	53	50.7
K (Colwell mg/kg)	618	534	443	531
S (KCl 40 mg/kg)	***3***	***6***	***7***	***5.3***
Soil stability	low	low	low	low
Ca – exch (cmol/kg)	6.40	9.42	7.29	7.70
Mg – exch (cmol/kg)	2.68	3.35	2.79	2.94
K – exch (cmol/kg)	1.59	1.46	1.14	1.40
Na – exch (cmol/kg)	***0.11***	***0.17***	***0.24***	***0.17***
Al – exch (cmol/kg)	***0.04***	***0.04***	***0.05***	***0.043***
Cu (DTPA mg/kg)	2.4	2.6	2.5	2.5
Zn (DTPA mg/kg)	0.4	0.5	0.3	0.4

Mn (DTPA mg/kg)	24	19	16	19.7
Fe (DTPA mg/kg)	8	7	6	7.0
B ($CaCl_2$ mg/kg)	1.3	1.5	1.3	1.37
Cl (1:5 mg/kg)	***4***	***5***	8	***5.7***
Al ($CaCl_2$ mg/kg)	0.2	0.2	0.2	0.2

* Bold and Italics are marginal on the CSBP results printout

A target yield of 1.0 t/ha was chosen and the CSBP recommended rate of 70 kg/ha Agras fertiliser (16.1%N, 9.1%P, 14.3%S, 0.5%Ca, 0.06%Zn) was used. The P and S were marginal as was the organic carbon. No nitrogen was needed but Agras was selected to be the same as the Merredin trial and should reduce the effect of the low P and S status.

Extra treatments were included in 2015 from buffer plots from 2014 but only plots set up in 2014 are included in this analysis. The control 300mm row spacings had a few more plants than other treatments (Table 6). The yields were variable with no clear meaningful differences (Table 6).

Table 6 Wheat plant density and yield with treatment at Southern Cross

Treatment	Plant density* (pl/m^2)	Yield* (t/ha)
1. Control 300 mm spacing	70.5 a	0.916 ab
2. FFIC 300 mm spacing	64.1 ab	0.894 abc
3. Control 375 mm spacing	62.2 bc	0.957 a
4. FFIC 375 mm spacing	62.8 bc	0.843 c
5. Control 460 mm spacing	57.8 bc	0.839 c
6. FFIC 460 mm spacing	57.0 bc	0.897 abc
7. FFIC Zeba 2 kg/ha 375 mm spacing	61.7 bc	0.858 bc
8. FFIC Zeba 4 kg/ha 375 mm spacing	56.3 c	0.837 c
Lsd ($p<0.05$)	7.64	0.0709
F pr	0.018	0.018
Coefficient of variation (%)	8.4	5.5

* Similar letters after the number are not significantly different at the 5% level.

In a sub-experiment within this trial at Southern Cross, black plastic sheet was put on the inter-rows to maximise the water harvesting from the row walls into the furrows. This was a single plot 4.8m long which yielded 1.65 t/ha so this indicates the potential for water harvesting to double yields (Figure 5).

Figure 5. Harvesting the 6m of black plastic covered inter-row of the FFIC460mm treatment.

The grain quality was assessed with an Infratec at CBH Merredin with only small treatment differences found in protein and gluten and the seed weight showed no significant differences (Table 7).

Table 7. Wheat quality traits with treatment at Southern Cross

Treatment	Protein* (%)	Gluten* (%)	Hardness index	Seed weight (g/1000)
1. Control 300 mm spacing	12.8 c	31.5 c	30.8	32.7
2. FFIC 300 mm spacing	12.9 c	32.4 bc	30.1	32.3
3. Control 375 mm spacing	13.3 abc	33.3 abc	28.4	33.1
4. FFIC 375 mm spacing	13.8 a	34.8 a	29.5	33.0
5. Control 460 mm spacing	13.3 abc	33.5 ab	28.4	33.1
6. FFIC 460 mm spacing	13.2 bc	32.8 bc	30.2	33.1
7. FFIC Zeba 2 kg/ha 375 mm spacing	13.6 ab	34.0 ab	29.0	33.1
8. FFIC Zeba 4 kg/ha 375 mm spacing	13.3 abc	32.9 bc	31.2	33.1
Lsd ($p<0.05$)	0.51	1.81	n.s.	n.s.
F pr	0.013	0.039	0.127	0.105
Coefficient of variation (%)	2.6	3.7	5.2	1.3

* Similar letters after the number are not significantly different at the 5% level.

4. Discussion of Southern Cross Results:

The very dry spring and very late sowing reduced yields and no clear yield differences were found across treatments. This may have been due to the high rainfall in March which would have benefited the conventional treatments as the soil profile would have been relatively full at the start of the season which is unusual and then the dry September would not have allowed any water harvesting (Table 8). However a 4.8m section of one plot of FFIC460mm with the inter-row covered in heavy black plastic yielded double at 1.65 t/ha. This indicates great potential for improved water harvesting with perhaps some form of spray on inter-row non-wetting agent or polymer product used in conjunction with the Wesley Wheels.

Table 8. Rainfall at the Southern Cross Airport, 5km from the site.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2015	0.0	13.0	75.6	18.4	12.4	33.8	54.4	82.6	2.8	43.0	18.2	4.2	358.4
Mean	28.9	23.3	36.2	24.0	28.8	26.7	34.6	30.3	21.9	16.8	18.1	15.4	305.0
Median	27.0	13.8	23.2	23.0	18.2	18.0	35.4	20.6	19.2	7.6	17.8	9.2	233.0

Implications:

In 2015, there were no significant treatment differences associated with the FFIC treatments, but this was likely because of (i) low end of season rainfall, (ii) installation of the FFIC treatments only just before the break of the season which eliminated the potential capture of summer rainfall, (iii) an inability to make adequate measurements of water harvesting in multiple sites to compare Control (conventional no till) with FFIC, (iv) inadequate field/environment locations for field trials, and (v) the need for expansion into trials with another crop (canola at Merredin) due to Crown Rot limitations. These constraints were exacerbated by reductions in and constraints to staffing positions experienced by DAFWA over 2015.

There were positive results from associated trials in 2015. Firstly, the black plastic used to cover inter-rows at Southern Cross indicated that yields can be improved (doubled) with better water harvesting under the existing natural conditions. This work suggests that other research on water harvesting products could realise higher gains if used in association with the Wesley Wheel concept.

Secondly, in a bulk paddock at Southern Cross using FFIC without Controls, there was good evidence that barley had substantially higher grain yields than normal (see below).

Such results highlight the need for further rigorous testing of FFIC (i) using replicated trials (ii) with controls (iii) focusing on a single crop (wheat) in (iv) multi-locational areas. The measurement of soil water in these diverse treatments of row spacings and inter-row compaction will be essential to enable interpretation of results and optimisation of soil management methodologies. Other opportunities identified here include the possibility to evaluate water repellent polymers on compacted inter-rows and the potential to model some of the rainfall patterns with water harvesting potential. The latter is important given that a small number of high intensity rainfall events will be much more likely harvested than a large number of low intensity rainfall events.

Publications:

Wesley C., G. Riethmuller, E. Barrett-Leonard and T. Setter (2015) Furrow formation and Inter-row Compaction (FFIC) for Improved Wheat Production in Water-limited Environments of the Eastern Wheatbelt of WA Agribusiness Crop Updates, Crown Perth, 24-25 Feb.

Recommendations:

Attention to sowing depth is important for canola with seeder changes as this can affect plant density and therefore potentially yield.

Given the combined constraints on the trial work detailed above, there is only subtle benefits at this stage to the concepts output. However, we do believe that now we have eliminated teething issues and constrains, another trial season would be highly beneficial to producing solid data. After the GRDC Groundcover magazine article, Callum Wesley received numerous calls from interstate farmers who were intrigued by the concept.

The water harvesting effect probably needs enhancing to approach the idea of plastic or other substance over the inter-row. A polymer or similar product could potentially be sprayed after the wheels on the inter-row to enhance water harvesting.

An extension of the project is desired if Callum can be appointed by DAFWA for seeding in April in 2016 for Mullewa, Merredin and Southern Cross. However, at this stage with a whole of government appointment freeze, it is not clear if this can be achieved. If this is not an option a fall back position is that another GRDC project on sodic and magnesic soils by Ed Barrett-Lennard may include the Wesley Wheels at sites at Kalannie, Bonnie Rock and Moorine Rock. This is because the Wesley Wheels indicated a small barley yield benefit at Nangeenan in 2015.

What is clear from past trials is that this work requires a team of growers and scientists (agronomists, soil scientists, physiologists, agric engineering, biometricians) working in key target environments.

Appendices

Callum Wesley used a set of wheels on his 13.4m wide farm seeder at 375 mm row spacing in 2015 on a barley paddock opposite the trial site paddock. On 11 June it was looking very stressed (Figure 6). Unfortunately there was no control strip done to compare with and without the wheels in this paddock.


Figure 6. Callum Wesley looking at very stressed barley on 11 June 2015.

However, by 19 September the barley was looking in excellent shape (Figures 7 and 8). This barley crop yielded 2.5 t/ha after some hail damage.

Figure 7. Michael Setter, John Wesley (Callum's father) and Callum Wesley, 19 September (photo by Tim Setter).

Figure 8. Callum Wesley with one barley plant grown on compacted inter-rows at Southern Cross, WA September 2015 (photo by Tim Setter).