Final Technical Report

2019 - 2021
Final Report

Reefinator Depth Trials in the medium rainfall zones of the South Eastern Kwinana zone of Western Australia

Project code: Reefinator Depth Trials

Prepared by: Corrigin Farm Improvement Group

Veronica Crouch
Corrigin Farm Improvement Group

Daniel Hester
Pedaga Investments

Date submitted: 5 January 2022

KEY MESSAGES

- The primary objective of the project was to evaluate the impact on grain production of reefinating suitable soils at 2 different depths (200mm and 400mm) within the south eastern Kwinana zone of Western Australia.

- The second objective of the project was to evaluate different starter fertiliser rates on grain production at the two different reefinating depths.

- The project was held across two sites and conducted over 3 years to help understand the longer-term impacts of reefinating

- Across both sites for the three season there was no significant yield uplift in reefinating the soil. There was no discernible pattern across either site or season with the yields across the different treatments contained to a tight band each season.

- Similarly, to the reefinating trial there was no significant yield improvement from applying higher rates of fertiliser between the low/medium/high rate. The high and low rate fertiliser trial (6 and 12 units of P) conducted at the Gorge Rocks site over the last two seasons demonstrated there is a clear yield advantage in applying fertiliser at higher rates in a good season like 2021.

- The key outcomes from the project are:

    - Spend the time in determining which soil types and areas should be reefinated as a positive yield response does not occur on all soil types.

    - Higher fertiliser rates will improve yield potential especially in better seasons

    - Seeing discernable yield differences between small differences in fertiliser rates can be challenging in grower demonstration style trials.

Further work is required to categorize rock/soil types in relation to there ability to respond to reefinating

SUMMARY

The Reefinator is a newly designed rip and roll method of digging up and crushing rock for broad acre and large paddock applications. Used in a multi pass process the Reefinator can leave a 4-6" deep seed bed of mixed rock and top soil which allows future sowing activities to be performed with minimal damage to machinery and increases productivity by not having to go around rocky nibs and outcrops. Plus in addition to crushing rocks can be a cultivation effect, which in forest gravel-type soils in particular, can assisted with issues of waterlogging/non-wetting, rhizoctonia and soil pathogen management and crop or pasture seed germination.

The primary objective of the project is to evaluate the impact on grain production of reefinating soils at 2 different depths within the south eastern Kwinana zone of Western Australia. The second objective of the project is to evaluate different starter fertiliser rates on grain production at the two different depths of reefinating

The project was held across two sites and conducted over 3 years to help understand the longer-term benefits of reefinating. The methodology of the project examined reefinating at 2 different depths 200mm and 400mm and then sowing the crop with different fertiliser rates (low, medium, high) across both depths using a common compound seeding fertiliser plus a treatment of triple single super. The sites were located at Bullaring and George Rock.

The reefinating component of the project unexpectedly didn't demonstrate an advantage in yield or returns to reefinating the chosen sites at either depth of 200mm or 400 mm. Across both sites for the three season there was no significant yield uplift in reefinating the soil and across the trials the control plot or area not reefinated was often one of the highest yielding plots. There was no discernible pattern across either site or season with the yields across all the different plots contained in a tight band each season.

Similarly, to the reefinating trial there was no significant yield improvement from applying higher rates of fertiliser between the low/medium/high rates. The high and low rate fertiliser trial (6 and 12 units of P) conducted at the Gorge Rocks site over the last two seasons demonstrated there is a clear yield advantage in applying fertiliser at higher rates especially in a good season like 2021

Overall, while the outcomes from the project were not in line with the initial expectations there were some clear take away messages from the project which will help producers moving forward. These messages are:

- Spend the time in determining which soil types and areas should be reefinated as a positive yield response does not occur on all soil types.
- Higher fertiliser rates will improve yield potential especially in better seasons
- Seeing discernable yield differences between small differences in fertiliser rates can be challenging in grower demonstration style trials.
- Further work is required to categorize rock/soil types in relation to there ability to respond to reefinating and the potential returns that can be achieved.

BACKGROUND

The Reefinator is a newly designed rip and roll method of crushing rock for broad acre and large paddock applications. The Reefinator is a multi-pass machine that digs up and crushes rock fast and efficiently. A towed implement, the Reefinator, designed to dig up common laterite rock or limestone, has a grate, much like a cheese grater, that holds down the rock and rips up manageable lumps that can be crushed by the following roller. Used in a multi pass process way the Reefinator will leave you with a 4-6" deep seed bed of mixed rock and top soil.

This allows future sowing activities to be performed with minimal damage to machinery and increases productivity by not having to go around rocky nibs and outcrops.

The 28 tonne machine acts much like a giant cheese grater, peeling away rock one layer at a time. The hydraulic tynes impact the surface to reduce the size and mass of the rock before the three metre wide, water-filled ribbed drum completes the pulverising process. As few as two or three passes will result in pea gravel sized crushed rock mixed with soil to a depth of up to 450mm – an ideal basis for growing a wide variety of crops and pastures.

The Reefinator can crush rocks at a hardness of about 70 megapascals (MPa), which is significantly denser than good concrete. In addition to the benefits of crushing rocks there is a cultivation effect, which in forest gravel-type soils in particular, can assisted with issues of waterlogging/non-wetting, rhizoctonia and soil pathogen management and crop or pasture seed germination.

The improved germination is applied to everything in the paddock, including weeds and can provide an excellent opportunity to manage the weed seedbank.

While the theory behind the reefinator in very sound there is limited R&D data to quantify the results and economic returns from what can be a considerable investment in soil amelioration. Costs can vary between $400/Ha to $800/Ha depending on the number of passes required to complete the operation. There is a requirement for more detailed research to aide producers in making the decision about whether and when it is worth reefinating country and the ultimate return from the investment.

OBJECTIVES

The objective of the project is to evaluate the impact on grain production of reefinating soils at 2 different depths within the south eastern Kwinana zone of Western Australia. The reefinating operation will occur in the Autumn prior to the first growing season and then the site will be monitor and crop production measured for the following three seasons to determine the immediate and longer-term impact on the yield following reefinating.

The second objective of the project is to evaluate different starter fertiliser rates on grain production at the two different depths of reefinating. The return on investment for each method will be evaluated to guide growers on the most profitable approach to improving the rocky unproductive soils/areas.

METHODS

The demonstrations were held across two sites and conducted over 3 years to help understand the longer-term benefits of reefinating. The methodology of the project examined reefinating at 2 different depths 200mm and 400mm and then sowing the crop with different fertiliser rates (low, medium, high) across both depths using a common compound seeding fertiliser plus a treatment of triple single super. The sites were located at Bullaring and George Rock.

Site 1 – Bullaring

Reefinator passes -

Rotation:

2017 – Pasture

2018 - Pasture

2019 – Wheat (Scepter)

2020 – Wheat (Scepter)

2021 – Barley (Spartacus)

Soil amelioration:

2 tons of lime was applied across the trial site in front of the reefinator in year 1 of the project.

Seeding fertiliser rates:

The seeding fertiliser rates used across the trial are outlined in table 1. Urea rates were varied across the treatments to apply the same amount of N for each treatment and leave high medium and low rates for P, K and S. Post seeding fertiliser was applied at the grower's standard practice.

	Fertiliser analysis		N	P	K	S
		Vigour	10	12	12	5
		Triple Super		20		
		Urea	46			
		Rate kg/Ha				
Vigour (med)	Vigour	100	10.0	12.0	12.0	5.0
	Urea	44	20.2			
		Total	30.2	12.0	12.0	5.0
Vigour (low)	Vigour	84	8.4	10.1	10.1	4.2
	Urea	48	22.1			
		Total	30.5	10.1	10.1	4.2
Vigour (high)	Vigour	117	11.7	14.0	14.0	5.9
	Urea	40	18.4			
		Total	30.1	14.0	14.0	5.9
Control	Vigour	100	10.0	12.0	12.0	5.0
	Urea	44	20.2			
		Total	30.2	12.0	12.0	5.0
Triple Super	Triple Super	68		13.6		
	Urea	65	29.9			
		Total	29.9	13.6	0.0	0.0

Table 1: Fertiliser rates by treatment applied across the Bullaring site at seeding.

The Bullaring site treatments are detailed in table 2. The treatments were applied across three replicates to enable data with statistical significance to be generated.

Site Layout

Treatment	Input (seeding)	@ Rate/ha	Reefinator Depth
1	CONTROL	Units: 12 P, 12 K, S = 100kg/ha	NOT REEFINATED
2	Vigour (Med)	Units: 12 P, 12 K, S = 100kg/ha	200 mm
3	Vigour (Med)	Units: 12 P, 12 K, S = 100kg/ha	400 mm
4	Vigour (Low)	Units: 10 P, 10 K, 4 S = 84kg/ha	200 mm
5	Vigour (Low)	Units: 10 P, 10 K, 4 S = 84kg/ha	400 mm
6	Vigour (High)	Units: 14 P, 14 K, 5.85 S = 117kg/ha	200 mm
7	Vigour (High)	Units: 14 P, 14 K, 5.85 S = 117kg/ha	400 mm
8	Triple Single Super	Units: 14 P = 68kg/ha	200 mm
9	Triple Single Super	Units: 14 P = 68kg/ha	400 mm

Table 2: Bullaring site treatment layout.

Site 2 – Gorge Rock

Reefinator passes -

Rotation:

2017 – Pasture

2018 – Bonito Canola

2019 – Wheat (Scepter)

2020 – Barley

2021 – Wheat (Noodle)

Soil amelioration:

2 tons of lime was applied across the trial site in front of the reefinator in year 1 of the project.

2019 Seeding fertiliser rates:

The seeding fertiliser rates used across the trial were designed as a seeding compound rate trial with three rates of K Till Max at low (80 kg/Ha) medium (100 kg/Ha) and high (120 kg/Ha). Post seeding fertiliser was applied at the grower's standard practice.

2019 Site Layout

Treatment	Input (seeding)	@ Rate/ha	Reefinator Depth
1	K Till Max (M)	Units: 9.6 N, 9.4 P, 15 K, 6.5 S = 100kg/ha	NOT REEFINATED
2	K Till Max (M)	Units: 9.6 N, 9.4 P, 15 K, 6.5 S = 100kg/ha	200 mm
3	K Till Max (M)	Units: 9.6 N, 9.4 P, 15 K, 6.5 S = 100kg/ha	400 mm
4	K Till Max (L)	Units: 7.6 N, 7.5 P, 12 K, 5.2 S = 80kg/ha	200 mm
5	K Till Max (L)	Units: 7.6 N, 7.5 P, 12 K, 5.2 S = 80kg/ha	400 mm
6	K Till Max (H)	Units: 11.5 N, 11.2 P, 18 K, 7.8 S = 120kg/ha	200 mm
7	K Till Max (H)	Units: 11.5 N, 11.2 P, 18 K, 7.8 S = 120kg/ha	400 mm
8	Double Phosphate	Units: 14 P = 80kg/ha	200 mm
9	Double Phosphate	Units: 14 P = 80kg/ha	400 mm

Table 3: Gorge Rock site 2019 treatment layout.

2020 and 2021 Seeding fertiliser rates:

The fertiliser rate trial was amended in 2020 and 2021 to a high and low rate of phosphorus which was seeded on top of the 2019 treatments as shown in table 4. The compound applied at seeding was 50% MacroPro Extra and 50% K-Till Extra Plus with 115 kg/Ha being the high rate and 60 kg/Ha the low rate. Post seeding fertiliser was applied at the grower's standard practice.

2020 and 2021 Site Layout

Treatment number	Input 2020/2021	Input 2019	Reefinator Depth
1	P:12 units	K Till Max (M)	NOT REEFINATED
2	P:12 units	K Till Max (M)	200 mm
3	P:12 units	K Till Max (M)	400 mm
4	P:12 units	K Till Max (L)	200 mm
5	P:12 units	K Till Max (L)	400 mm
6	P:12 units	K Till Max (H)	200 mm
7	P:12 units	K Till Max (H)	400 mm
8	P:12 units	Double Phosphate	200 mm
9	P:12 units	Double Phosphate	400 mm
10	P:6 units	K Till Max (M)	NOT REEFINATED
11	P:6 units	K Till Max (M)	200 mm
12	P:6 units	K Till Max (M)	400 mm
13	P:6 units	K Till Max (L)	200 mm
14	P:6 units	K Till Max (L)	400 mm
15	P:6 units	K Till Max (H)	200 mm
16	P:6 units	K Till Max (H)	400 mm
17	P:6 units	Double Phosphate	200 mm
18	P:6 units	Double Phosphate	400 mm

Table 3: Gorge Rock site 2020 and 2021 treatment layout.

Measurements recorded for the trial at both sites throughout the season:

- Pre-season comprehensive soil testing (soil depth; 0-10cm, 10-20cm increments).
- Surface Condition Score
    - 1 - well structured/minimal no crusting
    - 2 - rocky but not ripped
    - 3 - severe crusting
    - 4 - cultivated; rocky
    - 5 - cultivated; good tilth
- In season stubble condition score (% remaining)
- Plant establishment GS.13
- NDVI at GS.14 and GS.32 using a handheld Greenseeker
- Soil Moisture GS.14 and GS.45 measured as % water volume.
- Grain yield and grain quality
- Monthly rainfall

LOCATION

	Latitude (decimal degrees)	Longitude (decimal degrees)
Trial Site:	S32.37467	E117.91690
Nearest Town	Gorge Rock	
Trial Site:	S32.49520	E117.74479
Nearest Town	Bullaring	

RESULTS

Bullaring Site 2019 Results

Four sites across the trial were soil tested to a depth of 200mm at increments of 0-10cm and 10-20cm across the Bularing site. The fertility of the site improved from east to west with the western side of the trail area being point 1 and having the best Phosphorus, Potassium and organic carbon levels. The triple replication of the demonstration should account for this change in fertility across the site.

Overall the site shows reasonable fertility with good top soil pH level in CaCl between 5.2 – 6.3 and strong organic carbon levels between 0.86% – 1.67% in the top 10cm.

Date	Location	Point	Depth (cm)	pH [Ca]	PBI	P Col (mg/kg)	K Col (mg/kg)	OC (%)	Texture
24/04/2019	Bullaring	1	0-10	6.1	72	21	180	1.67	Sandy loam
24/04/2019	Bullaring	1	10-20	5.5	89	24	120	1.39	Sandy loam
24/04/2019	Bullaring	2	0-10	5.3	59	24	220	1.46	Loamy sand
24/04/2019	Bullaring	2	10-20	4.8	80	12	130	0.91	Sandy loam
24/04/2019	Bullaring	3	0-10	5.2	26	16	110	0.86	Sand
24/04/2019	Bullaring	3	10-20	4.6	32	8	100	0.34	Sandy loam
24/04/2019	Bullaring	4	0-10	6.3	12	14	71	1.06	Sand
24/04/2019	Bullaring	4	10-20	5.3	32	18	41	0.63	Sand

Table 1: Soil test results for the Bullaring site 2019.

Table 2 summarises the results for the Bullaring site taken across the 2019 growing season. The surface conditions and remaining stubble results were as expected in the year of the reefinating operation. The control or 'not reefinated' plots had the highest remaining stubble and surface score.

There were no significant differences between the treatments in regard to reefinating and/or fertiliser rates however, there were some interesting observations to be taken away:

- The control plot had the highest plant establishment and early NDVI reading (GS.13)
- Plant establishment was generally higher in the 200mm plots compared to the 400mm plots
- The control plot generally had the lowest soil moisture
- The later in season NDVI saw all the plots even up in reading irrespective of treatment.
- The yields were very even across all the treatments however in general the 400mm reefinating did yield higher than the 200mm reefinating.

Input at Seeding	Reefinator Depth	Surface Conditions	Stubble (% remaining)	Plants/m2 GS.13	NDVI GS.14	Soil Moisture GS.14	NDVI GS.32	NDVI GS.45	Soil Moisture GS.45	Yield MT/Ha
Vigour (Med)	NOT REEFINATED	5	46.3	149	0.20	5.77	0.41	0.52	0.26	2.07
Vigour (Med)	200 mm	1	3.9	132	0.17	6.36	0.44	0.54	0.34	1.93
Vigour (Med)	400 mm	0	2.4	128	0.16	7.02	0.49	0.57	0.51	2.17
Vigour (Low)	200 mm	1	6.6	144	0.17	8.04	0.44	0.55	0.17	2.02
Vigour (Low)	400 mm	1	2.0	135	0.16	7.38	0.47	0.56	0.34	2.11
Vigour (High)	200 mm	1	3.6	139	0.18	7.50	0.43	0.53	0.40	2.03
Vigour (High)	400 mm	1	3.4	125	0.16	6.44	0.46	0.53	0.25	2.00
Triple Single Super	200 mm	1	6.2	135	0.16	7.13	0.41	0.53	0.59	1.94
Triple Single Super	400 mm	1	2.8	126	0.15	8.53	0.46	0.56	0.52	2.12

Table 2: 2019 Bullaring demonstration site results summary

Chart 2 shows the yields by treatment at the Bullaring site in 2019. The highest yielding plot was the 400mm deep reefinated plot with medium compound fertiliser at 2.17 MT/Ha. The band from highest yielding to lowest yielding plot was very narrow ranging from 1.93 MT/Ha to 2.17 MT/Ha or a band of 0.24 MT/Ha.

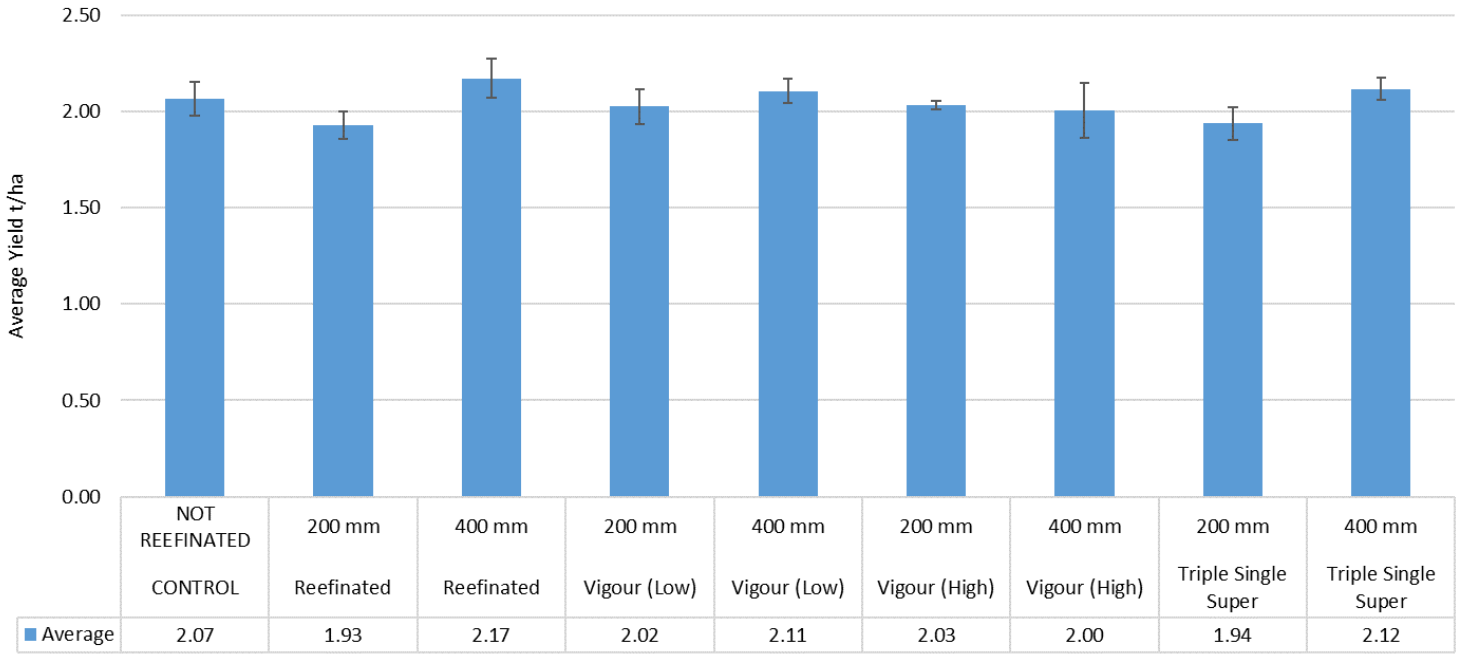


Chart 1: Bullaring 2019 yield results

Gorge Rocks 2019 Site Results

Three sites across the trial were soil tested to a depth of 200mm at increments of 0-10cm and 10-20cm across the Gorge Rock site. Overall the site demonstrates strong fertility with good top and mid soil pH levels in CaCl between 5.7 – 6.0 and very strong organic carbon levels in the top 10cm between 1.6 – 2.3%.

Potassium levels are very strong indicating the site shouldn't require additional K and there is good phosphorus level in the top 10cm which is typical of a long term synthetic fertiliser site. PBI's are medium to high showing the site could respond to increasing phosphorus rates with some P expected to be tied up by the soil each year.

Date	Location	Point	Depth (cm)	pH [Ca]	PBI	P Col (mg/kg)	K Col (mg/kg)	OC (%)	Texture
26/04/2019	Gorge Rock	A	0-10	5.8	109	32	167	2.2	Sandy loam
26/04/2019	Gorge Rock	A	10-20	6	117	4	84	1.4	Sandy loam
26/04/2019	Gorge Rock	B	0-10	6	92	29	315	2.3	Sandy loam
26/04/2019	Gorge Rock	B	10-20	5.8	76	3	86	0.6	Sandy loam
26/04/2019	Gorge Rock	C	0-10	5.7	103	21	240	1.6	Loam
26/04/2019	Gorge Rock	C	10-20	5.8	88	7	184	0.8	Sandy loam

Table 3: Soil test results for the Gorge Rock site 2019.

Table 4 summarises the results for the Gorge Rock site taken across the 2019 growing season. The results were very similar to the Bullaring site. The surface conditions and remaining stubble results were as expected in the year of the reefinating operation. The control or 'not reefinated' plots had the highest remaining stubble and surface score.

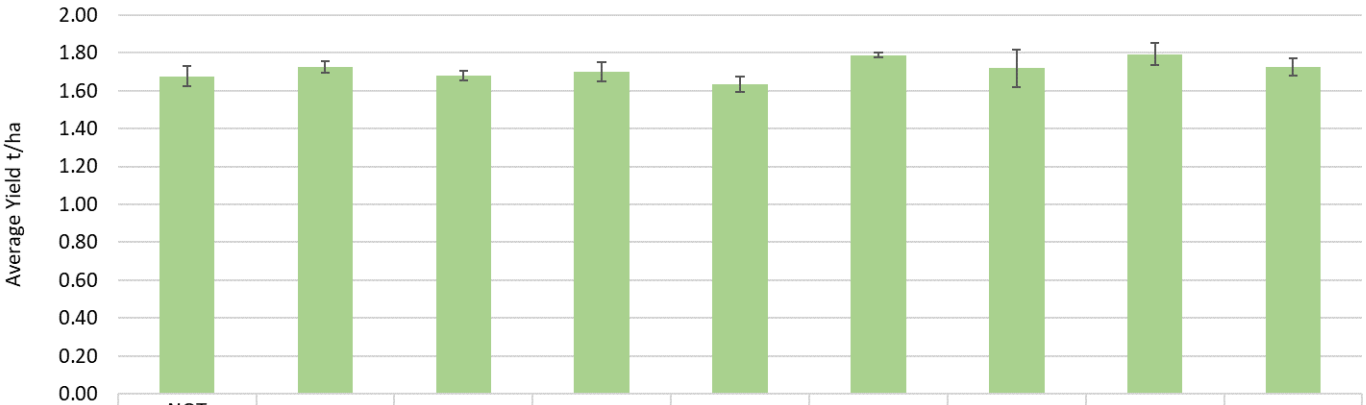
There were no significant differences between the treatments in regard to reefinating and/or fertiliser rates there were some interesting observations to be taken away:

- Plant establishment and all 3 NDVI reading were uniform across all treatments.
- Plant establishment was higher in all the 200mm plots compared to the 400mm plots.
- The control plot had the lowest soil moisture.
- The yields were very even across all the treatments however in general the 200mm reefinating did yield higher than the 400mm reefinating, which was the opposite result to Bullaring.

Input at Seeding	Reefinator Depth	Surface Conditions	Stubble (% remaining)	Plants/m2 GS.13	NDVI GS.14	Soil Moisture GS.14	NDVI GS.31	NDVI GS.45	Soil Moisture GS.45	Yield MT/Ha
K Till Max (M)	NOT REEFINATED	1	46.3	136	0.12	13.83	0.31	0.36	7.23	1.68
K Till Max (M)	200 mm	5	3.9	135	0.12	16.10	0.30	0.37	8.12	1.73
K Till Max (M)	400 mm	5	2.4	131	0.11	15.30	0.28	0.39	6.73	1.68
K Till Max (L)	200 mm	5	6.6	141	0.11	15.73	0.28	0.38	6.97	1.70
K Till Max (L)	400 mm	5	2.0	135	0.10	14.69	0.28	0.37	6.71	1.63
K Till Max (H)	200 mm	5	3.6	140	0.12	15.65	0.34	0.42	7.11	1.79
K Till Max (H)	400 mm	5	3.4	129	0.11	14.73	0.30	0.39	7.09	1.72
Double Phosphate	200 mm	5	6.2	139	0.10	14.53	0.30	0.39	6.91	1.79
Double Phosphate	400 mm	5	2.8	121	0.11	15.54	0.29	0.40	8.30	1.73

Table 4: 2019 Gorge Rock demonstration site results summary

Chart 2 shows the yields by treatment at the Gorge Rock site in 2019. The highest yielding plots were the 200mm deep reefinated plot with either the high compound fertiliser rate or the double phosphate. Similarly, to Bullaring the band from highest yielding to lowest yielding plot was very narrow ranging from 1.63 MT/Ha to 1.79 MT/Ha or a band of 0.16 MT/Ha.



	NOT REEFINATED K Till Max (M)	200 mm K Till Max (M)	400 mm K Till Max (M)	200 mm K Till Max (L)	400 mm K Till Max (L)	200 mm K Till Max (H)	400 mm K Till Max (H)	200 mm Double Phosphate	400 mm Double Phosphate
Average	1.68	1.73	1.68	1.70	1.63	1.79	1.72	1.79	1.73

Chart 2: Gorge Rock 2019 yield results

Bullaring Site 2020 Results

Table 5 summarises the results for the Bullaring site taken across the 2020 growing season. Similarly to 2019 there was no significant differences between the treatments in regards to reefinating and/or fertiliser rates however there were some interesting observations to be taken away:

- Plant establishment was higher in all the 200mm plots compared to the 400mm plots
- Soil moisture was higher in all the 200mm plots compared to the 400mm plots
- NDVI reading at both Zadoc times were generally higher in the 200mm plots compared to the 400mm plots
- The better in season reading from the 200mm plots didn't translate into final yield. There yields were very even across the trial.

Input at Seeding	Reefinator Depth	Plants/m2 GS.14	NDVI GS.14	Soil Moisture GS.14	NDVI GS.31	NDVI GS.40	Yield MT/Ha
Vigour (Med)	NOT REEFINATED	124	0.10	7.91	0.32	0.51	2.58
Vigour (Med)	200 mm	129	0.10	7.77	0.35	0.55	2.39
Vigour (Med)	400 mm	111	0.08	7.16	0.31	0.50	2.59
Vigour (Low)	200 mm	123	0.08	8.44	0.35	0.54	2.57
Vigour (Low)	400 mm	120	0.09	7.03	0.33	0.56	2.58
Vigour (High)	200 mm	130	0.10	8.17	0.32	0.54	2.56
Vigour (High)	400 mm	100	0.08	7.21	0.30	0.54	2.55
Triple Single Super	200 mm	144	0.10	7.97	0.32	0.57	2.52
Triple Single Super	400 mm	123	0.09	7.69	0.32	0.54	2.59

Table 5: 2020 Bullaring demonstration site results summary

Chart 3 shows the yields by treatment at the Bullaring site in 2020. The highest yielding plot was again the 400mm deep reefinated plot with medium compound fertiliser as well as the 400mm deep reefinated plot with triple super both yielding 2.59 MT/Ha. However, the band from highest yielding to lowest yield plot was very narrow with 8 plots out of 9 yield ranging from 2.52 MT/Ha to 2.59 MT/Ha or a band of 0.07 MT/Ha. The 200mm deep reefinated plot with medium compound fertiliser yielded 2.39 MT/Ha marginally below the other treatments.

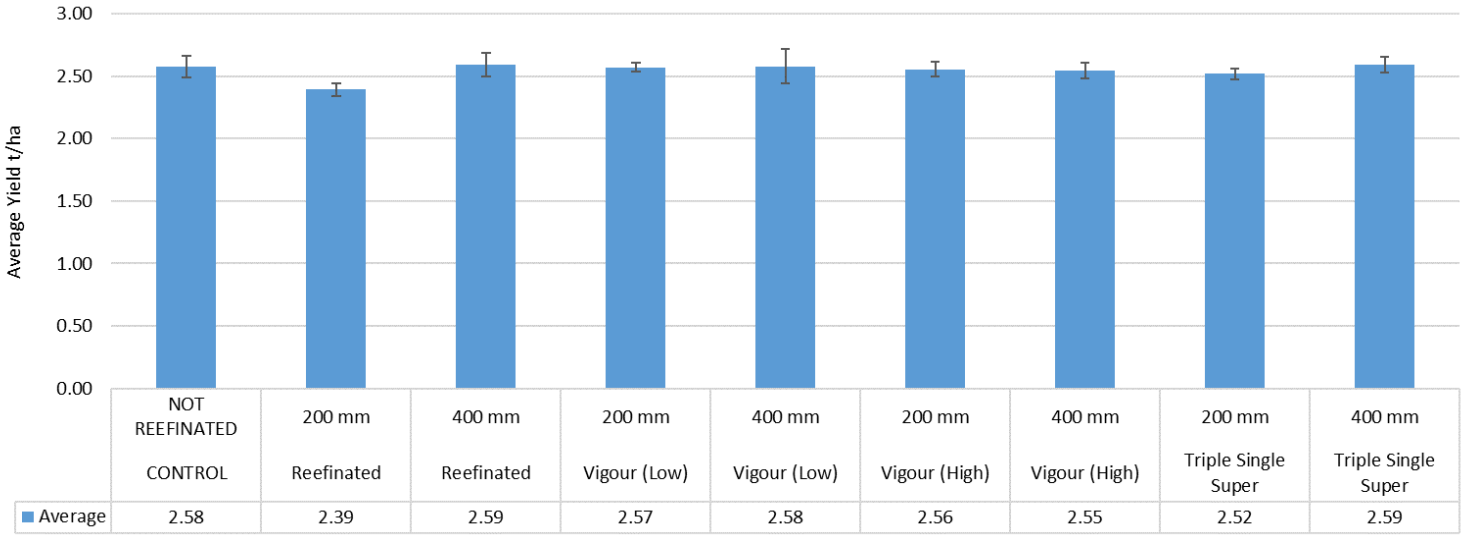


Chart 3: Bullaring 2020 yield results

Gorge Rocks 2020 Site Results

Table 4 summarises the results for the Gorge Rock site taken across the 2020 growing season. The fertiliser component of the trial was altered for the final two seasons of the project to be at a high and low rate of seeding compound fertiliser. Again there were no significant differences between treatments with the following observations from the trial:

- The high phosphorus plots on average yielded 2.03 MT/Ha compared to low phosphorus plots at 1.99 MT/Ha.
- There was no defined or general pattern from either of the treatments across the trial in regard to establishment, NDVI reading or soil moisture.
- All recordings were in a tight band across the different treatments.

2020 Input at Seeding	2019 Input at Seeding	Reefinator Depth	Plants/m2 GS.14	NDVI GS.14	Soil Moisture GS.14	NDVI GS.31	NDVI GS.45	Yield MT/Ha
P:12 units	K Till Max (M)	NOT REEFINATED	164	0.21	9.57	0.34	0.48	2.23
P:12 units	K Till Max (M)	200 mm	163	0.21	9.55	0.35	0.51	1.98
P:12 units	K Till Max (M)	400 mm	168	0.20	8.61	0.34	0.49	1.97
P:12 units	K Till Max (L)	200 mm	161	0.22	9.00	0.35	0.51	2.05
P:12 units	K Till Max (L)	400 mm	154	0.20	8.64	0.33	0.50	1.98
P:12 units	K Till Max (H)	200 mm	174	0.22	9.33	0.36	0.52	1.99
P:12 units	K Till Max (H)	400 mm	168	0.21	8.61	0.35	0.49	2.01
P:12 units	Double Phosphate	200 mm	175	0.22	8.99	0.34	0.50	2.11
P:12 units	Double Phosphate	400 mm	166	0.22	9.63	0.35	0.51	1.98
P:6 units	K Till Max (M)	NOT REEFINATED	159	0.20	9.28	0.28	0.43	1.92
P:6 units	K Till Max (M)	200 mm	165	0.19	10.17	0.28	0.44	2.04
P:6 units	K Till Max (M)	400 mm	179	0.19	9.90	0.27	0.46	2.04
P:6 units	K Till Max (L)	200 mm	162	0.21	9.72	0.30	0.45	1.84
P:6 units	K Till Max (L)	400 mm	150	0.19	9.19	0.27	0.45	2.04
P:6 units	K Till Max (H)	200 mm	169	0.20	9.57	0.30	0.44	2.02
P:6 units	K Till Max (H)	400 mm	171	0.19	9.31	0.26	0.41	1.98
P:6 units	Double Phosphate	200 mm	158	0.20	8.86	0.29	0.43	1.95
P:6 units	Double Phosphate	400 mm	167	0.19	9.46	0.25	0.41	2.09

Table 6: 2020 Gorge Rock demonstration site results summary

Chart 4 shows the yields by treatment at the Gorge Rock site in 2020. The highest yielding treatment was the control plot with 12 units of P at 2.23 MT/Ha followed by the 200mm deep reefinated plot with double phosphate.

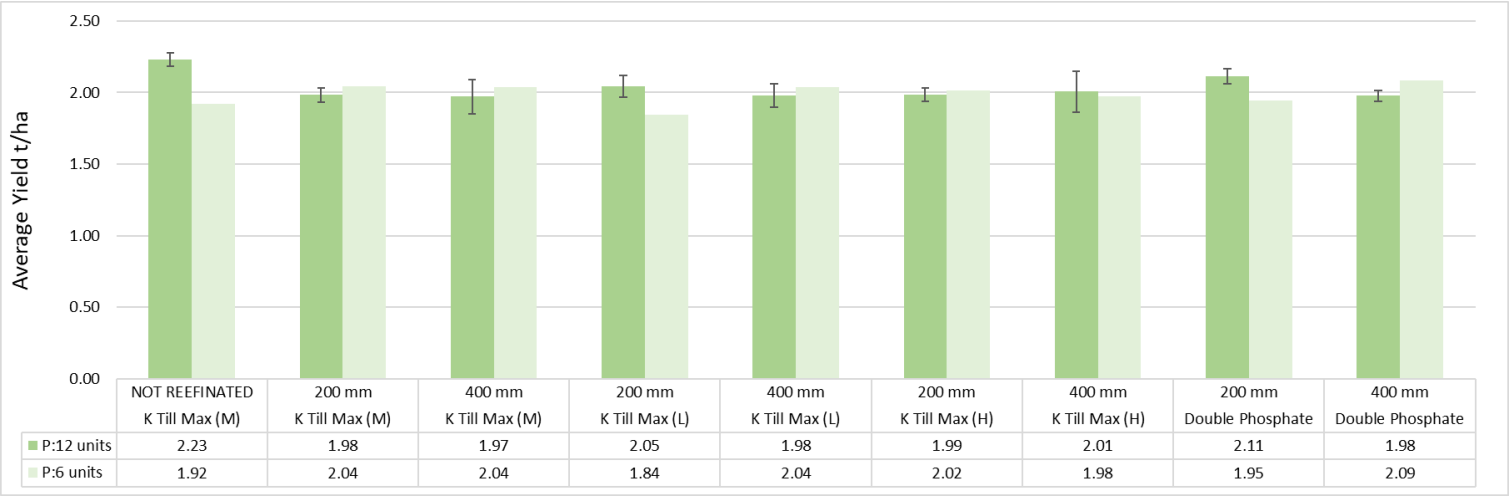


Chart 4: Gorge Rock 2020 yield results

Bullaring Site 2021 Results

Table 7 summarises the results for the Bullaring site taken across the 2021 growing season. The better growing season resulted in much higher average yields across the trial. There were no significant differences between treatments in terms of yield. The following observations were seen across the trial in 2021:

- Plant establishment was significantly higher in the 400mm deep triple super plot at 220 plant/m2.
- The high plant density resulted in the same treatment having the highest early NDVI reading although the treatments had evened up by the later reading at GS.31.
- The soil moisture at GS.14 was considerably higher in 2021 at 8.22% compared to the two previous seasons at the same growth time at 7.71% in 2020 and 7.13% in 2019.

Input at Seeding	Reefinator Depth	Plants/m2 GS.14	NDVI GS.14	Soil Moisture GS.14	NDVI GS.31	Yield MT/Ha
Vigour (Med)	NOT REEFINATED	111	0.14	7.62	0.70	4.84
Vigour (Med)	200 mm	108	0.13	8.27	0.69	4.70
Vigour (Med)	400 mm	116	0.13	7.68	0.65	4.48
Vigour (Low)	200 mm	122	0.13	8.86	0.70	4.82
Vigour (Low)	400 mm	115	0.13	7.73	0.67	4.67
Vigour (High)	200 mm	118	0.13	8.17	0.66	4.65
Vigour (High)	400 mm	107	0.13	8.08	0.66	4.43
Triple Single Super	200 mm	128	0.13	8.77	0.69	4.69
Triple Single Super	400 mm	220	0.18	8.78	0.69	4.89

Table 7: 2021 Bullaring demonstration site results summary

Chart 5 shows the yields by treatment at the Bullaring site in 2021. The highest yielding plot was the 400mm deep reefinated plot with triple super yielding 4.89 MT/Ha. This was one of the two equal highest yielding plots in 2020. Similar to the other 2 seasons the band from highest yielding to lowest yield plot was very narrow ranging from 4.48 MT/Ha to 4.89 MT/Ha or a band of 0.41 MT/Ha or roughly 9%.

Chart 6 shows the average yield by reefinator depth. The highest yielding average is the non reefinated control followed by the 200mm plots, with reefinating to 400mm resulting in the lowest average yield.

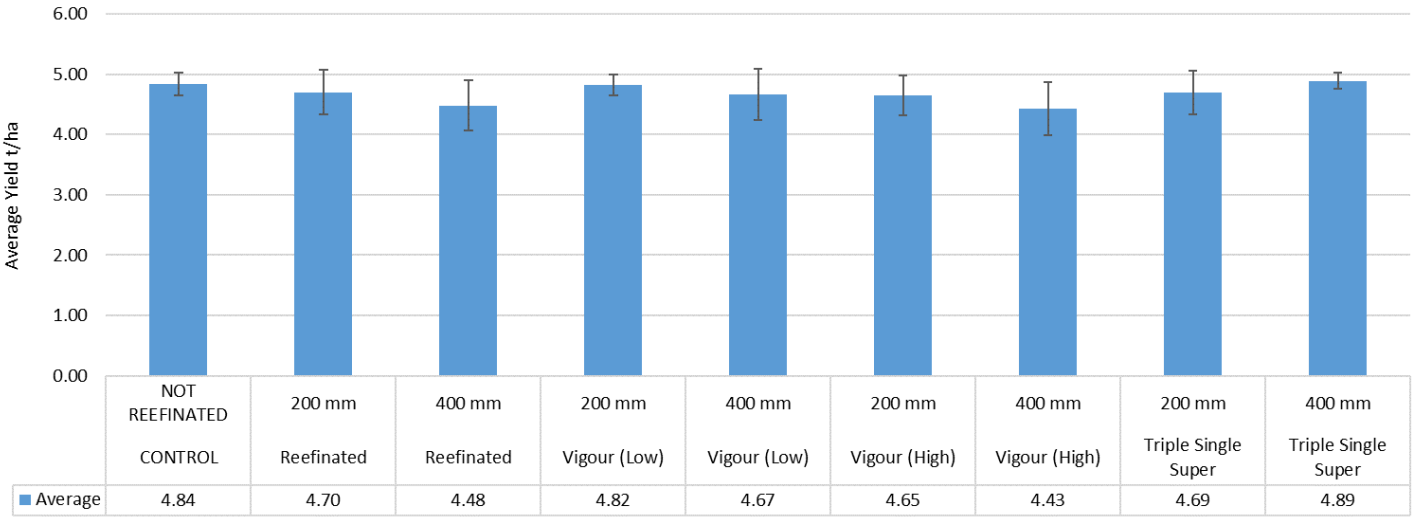


Chart 5: Bullaring 2021 yield results

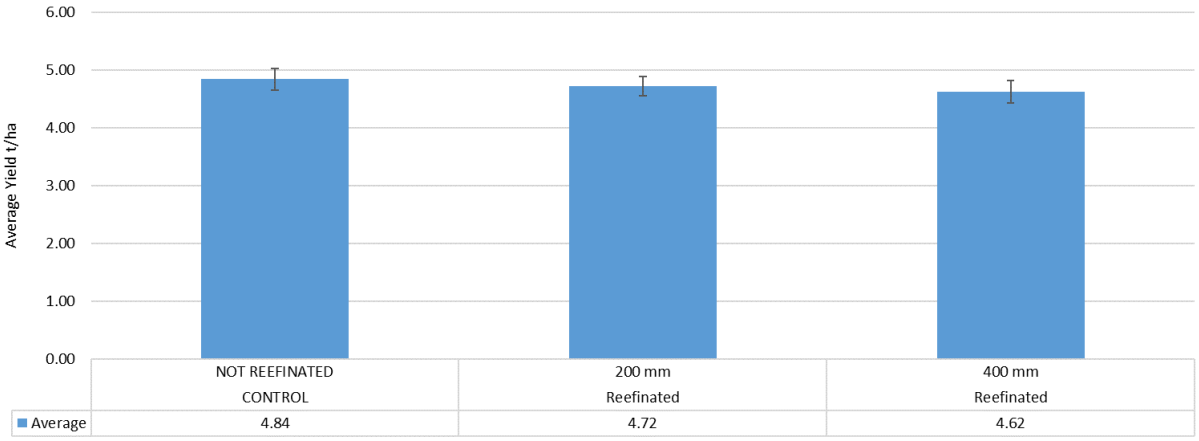


Chart 6: Bullaring 2021 yield average for each reefinating depth.

Gorge Rocks 2021 Site Results

Table 8 summarises the results for the Gorge Rock site taken across the final growing season, 2021. The high rate of phosphorus recordings was considerably higher than the low rate of phosphorus:

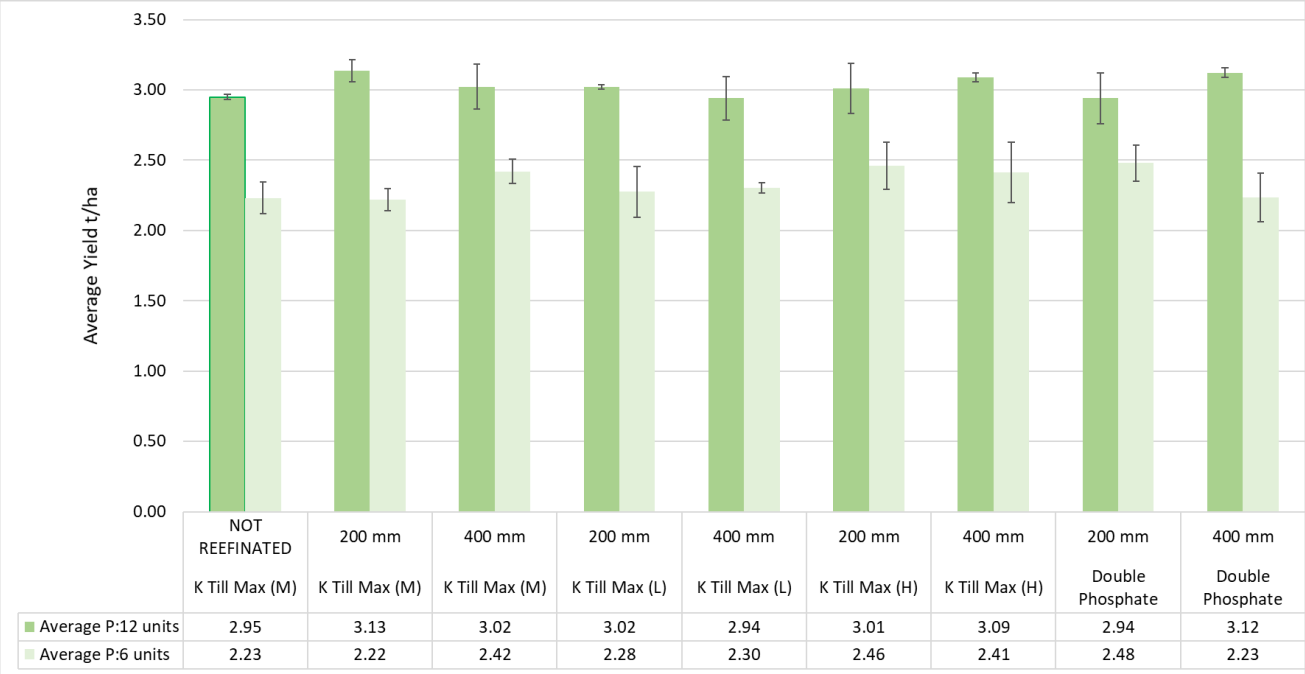
- The high phosphorus plots on average yielded 3.03 MT/Ha compared to low phosphorus plots at 2.34 MT/Ha.
- The high rate of phosphorus average NDVI reading was higher at the first reading GS.14, 0.20 vs 0.17 and this difference increased in line with yield potential to be 0.50 (high P) vs 0.41 (low P) at the GS31.
- There were no discernable patterns across the reefinated treatments and 2019 fertiliser treatments with recordings in a tight band across the different treatments.

2020 Input at Seeding	2019 Input at Seeding	Reefinator Depth	Plants/m2 GS.14	NDVI GS.14	Soil Moisture GS.14	NDVI GS.31	Yield MT/Ha
P:12 units	K Till Max (M)	NOT REEFINATED	175	0.19	16.48	0.47	2.95
P:12 units	K Till Max (M)	200 mm	188	0.20	18.79	0.51	3.13
P:12 units	K Till Max (M)	400 mm	188	0.19	15.52	0.49	3.02
P:12 units	K Till Max (L)	200 mm	179	0.20	18.28	0.49	3.02
P:12 units	K Till Max (L)	400 mm	169	0.20	16.90	0.52	2.94
P:12 units	K Till Max (H)	200 mm	161	0.20	19.29	0.51	3.01
P:12 units	K Till Max (H)	400 mm	177	0.20	16.75	0.50	3.09
P:12 units	Double Phosphate	200 mm	179	0.21	18.13	0.50	2.94
P:12 units	Double Phosphate	400 mm	187	0.21	18.83	0.50	3.12
P:6 units	K Till Max (M)	NOT REEFINATED	175	0.16	16.89	0.39	2.23
P:6 units	K Till Max (M)	200 mm	194	0.15	18.27	0.39	2.22
P:6 units	K Till Max (M)	400 mm	186	0.15	17.07	0.39	2.42
P:6 units	K Till Max (L)	200 mm	202	0.16	16.77	0.39	2.28
P:6 units	K Till Max (L)	400 mm	194	0.16	16.13	0.41	2.30
P:6 units	K Till Max (H)	200 mm	195	0.23	17.89	0.45	2.46
P:6 units	K Till Max (H)	400 mm	194	0.16	17.27	0.41	2.41
P:6 units	Double Phosphate	200 mm	293	0.16	16.45	0.43	2.48
P:6 units	Double Phosphate	400 mm	182	0.16	17.05	0.41	2.23

Table 8: 2021 Gorge Rock demonstration site results summary

Chart 7 shows the yields by treatment at the Gorge Rock site in 2021. The highest yielding treatment was the high rate of P, 200mm deep reefinated plot with the medium rate of K Till Max, followed by treatment with the high rate of P, reefinated to 400mm with the high rate of K till Max.

The high phosphorus rates yielded higher for every treatment compared to the low phosphorus rate. The average yield across all the reefinated plots for the high P rate was 3.04 MT/Ha compared to the control at 2.95 MT/Ha. There was a similar pattern in the low P treatments with the average yield across the reefinated plots being 2.35 MT/Ha compared to the control at 2.23 MT/Ha.



	NOT REEFINATED K Till Max (M)	200 mm K Till Max (M)	400 mm K Till Max (M)	200 mm K Till Max (L)	400 mm K Till Max (L)	200 mm K Till Max (H)	400 mm K Till Max (H)	200 mm Double Phosphate	400 mm Double Phosphate
Average P:12 units	2.95	3.13	3.02	3.02	2.94	3.01	3.09	2.94	3.12
Average P:6 units	2.23	2.22	2.42	2.28	2.30	2.46	2.41	2.48	2.23

Chart 7: Gorge Rock 2021 yield results

Gorge Rock 2021 Predicta B Results

Two Predicta B samples were taken at the Gorge Rocks across the site in 2021. The full results are available in appendix 1. At site one there were low to medium levels of Rhizoctonia, Crown Rot and Pratylenchus neglectus. At site two there were high levels of Rhizoctonia and low levels of Pratylenchus neglectus and Blackspot. The high levels of Rhizoctonia could result in yield losses between 20 – 50%

CONCLUSIONS

Yield improvements from Reefinating are largely influenced by the amount of rock in the soil prior to being reefinated. The more rock and the less soil the better the yield response is expected to be. For example, if an area is largely made up of lateritic rock and is not able to be seeded prior to reefinating, then the crop that is planted due the improvement in trafficability is a 100% yield increase.

Yield improvements can secondly come from the deep ripping effect of the tynes which can rip up to 400mm deep. Hard pans generally start at 300mm and by breaking up the hard pan roots are able to penetrate deeper into the soil to access more moisture and nutrients and improve plant resilience through dry periods.

Minor additional efficiencies are found through improved trafficability and better run lines reducing overlap and input waste.

The reefinating component of the project unexpectedly didn't demonstrate an advantage in yield or returns to reefinating the chosen sites at either depth of 200mm or 400 mm. Across both sites for the three season there was no significant yield uplift in reefinating the soil and across the trials the

control plot or area not reefinated was often one of the highest yielding plots. There were no discernible pattern across either site or seasons with the yields across all the different plots held in a tight band each season.

From the results from the trial conducted over three seasons the recommendation is to not reefinate soils. While this outcome is surprising, this is what the results have clearly shown. However, the more accurate recommendation is for producers to increase the due diligence on the areas or soils to be reefinated as an uplift in yield is not guaranteed and the high cost of the amelioration requires careful consideration.

The fertiliser trial conducted within the reefinating trial brought a complication to the overall project in an area that has been well researched in the past. The three rates of fertiliser low, medium and high or 10, 12 and 14 units of phosphorus at Bullaring and initially 7.5, 9.4 and 11.2 at Gorge Rock before changing to 6 and 12 units for the final two seasons in a demonstration style methodology was going to be difficult to achieve key deliverables from the results.

Similarly to the reefinating trial there was no significant yield improvement from applying higher rates of fertiliser between the low to medium to high. The yields across both sites and seasons were in a tight band, with the low rate of fertiliser often in the highest yielding plots. The impact of reefinating the plots may have impacted the outright results as impact from the process of reefinating, through the soil amelioration could influence the plants ability to utilise or access nutrients.

Achieving or seeing a significant yield differences between 2 units of P per hectare (focusing on the P rate) in a grower demonstration is improbable even though the expectation of increasing P rates will increase yield. From the results the outcome from the trial is to sow with the low rate of fertiliser as there is no yield improvement from increasing fertiliser rates even in high potential years like 2021.

The high and low rate fertiliser trial (6 and 12 units of P) conducted at the Gorge Rocks site over the last two seasons demonstrated there is a clear yield advantage in applying fertiliser at higher rates especially in a good season like 2021. There was no yield advantage in 2020 with a lower average of circa 2.00 ton/Ha (2.03 ton/Ha (high rate) vs 1.99 ton/Ha (low rate)) however when the yield potential increased to 3.00 ton/Ha the higher rate of fertiliser allowed the crop to take advantage of the improved seasonal conditions and yield on average 3.03 ton/Ha (high rate) vs 2.34 ton/Ha (low rate).

The Gorge Rocks trial demonstrates that higher rates of fertiliser does increase yield potential which is particularly relevant in high potential seasons. However in low yield potential seasons there is no advantage in increasing fertiliser rates.

Overall the outcomes from the project were not in line with the initial expectations however there were some clear take away messages from the project which will help producers moving forward. These messages are:

- Spend the time in determining which soil types and areas should be reefinated as a positive yield response does not occur on all soil types.
- Higher fertiliser rates will improve yield potential especially in better seasons
- Seeing discernable yield differences between small differences in fertiliser rates can be challenging in grower demonstration style trials.

- Further work is required to categorize rock/soil types in relation to there ability to respond to reefinating and the potential returns that can be achieved.

APPENDIX

Appendix 1 – Gorge Rock 2021 Predicta B results

PREDICTA B
DNA Soilborne disease tests

SARDI Plant & Soil Health
Gate 2B, Hartley Gr. P 08 8303 9360
URRBRAE SA 5064 F 08 8303 9393

Sample: AAG5060
Paddock: **2b**
Grower: **g fisher**

Report date: 27/08/2021
Sampling strategy: **Random**
Stubble added: **Yes**
Nearest town: **CORRIGIN**
Region: **Western**

Paddock history	2 years ago	Last year	This year
Crop / variety	Wheat / NINJA	Barley / BUFF	Wheat / NINJA

TEST	RESULT		DISEASE RISK* Not Detected / Low / Med / High
CCN	<0.05	eggs /g soil	
Stem nematode	<0.5	nematodes/100 g soil	
Take-all	<0.8	log(pg DNA/g soil)	
Take-all - Oat Strain	<0.8	log(pg DNA/g soil)	
Rhizoctonia	2.66	log(pg DNA/g soil)	
Crown rot	<0.1	log(pg DNA/g soil)	
Pratylenchus neglectus	0.2	nematodes /g soil	
Pratylenchus quasitereoides	<0.1	nematodes/g soil	
Blackspot	1.71	log(pg DNA/g soil)	
Blackspot (Phoma koolunga)	<1.2	log(pg DNA/g soil)	

*Risk categories should be used as a guide only, may be subject to regional and seasonal differences, and may be revised over time.

UNDER EVALUATION

TEST	RESULT		POPULATION DENSITY** Not Detected / Low / Med / High
Common root rot	2.01	log(pg DNA/g soil)	
Pythium clade f	<0.6	log(pg DNA/g soil)	
Yellow leaf spot	<0.3	log(kDNA copies/g soil)	
Eyespot	<0.3	log(kDNA copies/g soil)	
White grain disorder	<0.3	log(kDNA copies/g soil)	
Pratylenchus penetrans	<0.1	nematodes /g soil	
Pratylenchus thornei	<0.1	nematodes/g soil	
Charcoal rot	1.21	log(kDNA copies/g soil)	
Ascochyta blight of chickpea	<0.05	log(kDNA copies/g soil)	
Sclerotinia stem rot	<0.1	log(kDNA copies/g soil)	

**Population densities are based on the distribution of pathogen levels detected in PreDicta samples over several years. These are not disease risk categories.

CORRIGIN
Farm Improvement Group

PREDICTA B
DNA Soilborne disease tests

SARDI Plant & Soil Health
Gate 2B, Hartley Gr. P 08 8303 9360
URRBRAE SA 5064 F 08 8303 9393

Sample: AAG5061
Paddock: **2a**
Grower: **g fisher**

Nearest town: **CORRIGIN**

Report date: 27/08/2021
Sampling strategy: **Random**
Stubble added: **Yes**
Region: **Western**

Paddock history	2 years ago	Last year	This year
Crop / variety	Wheat / NINJA	Barley / BUFF	Wheat / NINJA

TEST	RESULT		DISEASE RISK*
			Not Detected / Low / Med / High
CCN	<0.05	eggs /g soil	
Stem nematode	<0.5	nematodes/100 g soil	
Take-all	<0.8	log(pg DNA/g soil)	
Take-all - Oat Strain	<0.8	log(pg DNA/g soil)	
Rhizoctonia	1.35	log(pg DNA/g soil)	
Crown rot	0.15	log(pg DNA/g soil)	
Pratylenchus neglectus	0.8	nematodes /g soil	
Pratylenchus quasitereoides	<0.1	nematodes/g soil	
Blackspot	<1.2	log(pg DNA/g soil)	
Blackspot (Phoma koolunga)	<1.2	log(pg DNA/g soil)	

*Risk categories should be used as a guide only, may be subject to regional and seasonal differences, and may be revised over time.

UNDER EVALUATION

TEST	RESULT		POPULATION DENSITY**
			Not Detected / Low / Med / High
Common root rot	1.34	log(pg DNA/g soil)	
Pythium clade f	0.72	log(pg DNA/g soil)	
Yellow leaf spot	<0.3	log(kDNA copies/g soil)	
Eyespot	<0.3	log(kDNA copies/g soil)	
White grain disorder	<0.3	log(kDNA copies/g soil)	
Pratylenchus penetrans	<0.1	nematodes /g soil	
Pratylenchus thornei	<0.1	nematodes/g soil	
Charcoal rot	0.79	log(kDNA copies/g soil)	
Ascochyta blight of chickpea	<0.05	log(kDNA copies/g soil)	
Sclerotinia stem rot	0.31	log(kDNA copies/g soil)	

**Population densities are based on the distribution of pathogen levels detected in PreDicta samples over several years. These are not disease risk categories.