Improving the Understanding of Nitrogen Use Efficiency and Soil Water Interactions

103MIG15

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Organisation: Mingenew Irwin Group, Agrarian Management Supported by: GRDC

GROWER: G COSGROVE B CRIPPS, R & A MESSINA, WESTERN AUSTRALIAN COLLEGE OF AGRICULTURE – MORAWA

Location: Mingenew, Ogilvie, Tenindewa, Morawa

Soil Type: Pale deep sand, yellow deep sand, red sandy earth

GSR (Apr-Sept):
Cosgrove: 183mm
Cripps: 189mm
Messina: 193mm
Morawa: 151mm

Paddock History:
2014 Cosgrove: Canola
Cripps: Canola,
Messina: Canola
Morawa Ag: Lupins

Paddock Avg Yield: Cosgrove 1.8t/ha, Cripps 2.0t/ha, Messina 1.4t/ha, Morawa Ag 2.1t/ha (frost damage in paddock reduced avg yield at Cripps site)

Plot Size: 2.0m x 20m

Trial Size: Small plot

Sowing Date: Cosgrove: 3rd May, Cripps: 29th April, Messina: 28th April, Morawa Ag: 30th April

Sowing Rate: 80kg/ha

Sowing Machinery: Cone seeder, knife points and press wheels

Variety: Mace

PADDOCK INPUTS

Fertiliser
At seeding: All trials sown with Super at P rates equivalent to grower paddock application.

Post N: Applied 17th June 2015

Section A. Soil Test Results

Soil results from sampling prior to seeding were used for soil characterization and to set the parameters in Yield Prophet and Crop Manager. The third yield prediction model analysed in this project, Ipaddock Yield, does not use soil test data, only historical yields and rainfall.

Table 1. Cosgrove, Pale deep sand

DEPTH	N	P	K	S	PH ($CaCl_2$)	OC%
0 – 10cm	21	13	47	15.6	6.3	0.56
10 – 20cm	11	16	42	10.7	6.1	0.32
20 – 30cm	8	10	26	7.2	6.1	0.17
30 – 40cm	4	10	22	4.8	6.2	0.10
40 – 50cm	3	8	17	2.2	5.8	0.06
50 – 80cm	2	7	66	6.0	6.2	0.13

Table 2. Cripps, Pale deep sand

DEPTH	N	P	K	S	PH ($CaCl_2$)	OC%
0 – 10cm	9	16	43	4.5	6.3	1.06
10 – 20cm	6	12	36	3.3	6.3	0.43
20 – 30cm	5	14	30	4.2	5.3	0.28
30 – 40cm	4	11	31	6.0	4.8	0.23
40 – 50cm	4	3	32	8.6	5.0	0.19
50 – 80cm	3	2	34	11.3	5.4	0.15

Table 3. Messina, Yellow deep sand

DEPTH	N	P	K	S	PH ($CaCl_2$)	OC%
0 – 10cm	5	11	21	3.2	6.5	0.41
10 – 20cm	7	18	20	3.2	6.5	0.57
20 – 30cm	5	14	16	2.3	6.2	0.40
30 – 40cm	4	14	19	2.1	5.8	0.27
40 – 50cm	3	12	22	2.5	5.3	0.14
50 – 80cm	2	4	18	3.8	5.9	0.09

Table 4. Morawa, Red Sandy Earth

DEPTH	N	P	K	S	PH ($CaCl_2$)	OC%
0 – 10cm	10	31	75	7.4	5.0	0.4
10 – 20cm	11	11	53	13	5.5	0.3
20 – 30cm	16	12	70	30.6	7.5	0.25
30 – 40cm	7	5	48	16.1	7.6	0.22
40 – 50cm	6	6	65	19.2	8.0	0.22
50 – 80cm	4	7	42	15.2	8.2	0.14

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WHY DO THE TRIAL?

The research aimed to demonstrate the concept of utilizing a range of technologies to monitor and improve Nitrogen use efficiency on four of the major soil types in the Northern Agricultural Region (NAR). The project and trial component of the research involved collaboration between MIG and Agrarian Management (AM) and the grower groups NAG, YFIG, MFIG, MDFI and NEFF to characterize the major soil types of this region.

The second component of the trial is to build an understanding of the current Nitrogen use efficiency on the four soil types and to measure how efficiently applied nitrogen is being utilized. With this information growers can make more confident and accurate decisions on nutrient application and grain marketing.

The research proposed is to develop a concept that growers can easily implement and access during the growing season, a concept that will provide them with real time information and improve confidence in crop performance and yield potential. This will allow growers to allocate nutritional inputs and market their grain based on informed knowledge.

When soil Nitrogen levels are tested to depth close to sowing, accurate soil profile nitrogen is known at seeding. Plant available nitrogen can be modelled at sowing to develop a Nitrogen response curve (as shown in Section C) and allowing informed growers to tailor nitrogen applications to a range of estimated yields, increasing their level of risk management and reducing the risk of either under or over fertilizing a particular soil type.

The next peace of the jigsaw is to know what the final yield is likely to be. Yield Estimation tools such as Yield Prophet, iPaddock Yield and the old water use efficiency calculators such as French & Shultz equations are all useful tools in predicting final yield. As part of this research, an evaluation of these tools has been conducted.

The models were run retrospectively, based on the previous 10 years of rainfall and paddock yield data for each research paddock in the project.

A yield estimate was produced as at the 31st July for each of the 10 years in the historical data and the following yield estimate accuracy was calculated. Below estimate accuracy figures are from the Cosgrove site.

1 Yield Prophet (APSIM)	68% accuracy
2 French & Shultz (Brocken Stick)	74% accuracy
3 iPaddock Yield	77% Accuracy

The more accuracy and confidence we have in the final yield estimate, the greater the ability to play the season with Nitrogen applications and maximize grain yield and profitability in any given season. Each season is different so an understanding of soil water holding capacity and plant available moisture in the soil throughout the season is essential to be able to estimate yield and tailor nitrogen applications. The knowledge and accuracy, thus confidence, that we have in this area is increasing rapidly.

Each site in this project went through the following process:
A) Selection and soil type characterization with water holding parameters identified
B) Particle size analysis has been used to set the Crop Lower Limit (CLL) and Drained Upper Limit (DUL) for each soil
C) A replicated nitrogen rate response trial was established and a soil moisture probe installed to a depth of 80cm
D) Registration for Yield Prophet and real time data from the probe fed into Crop Manager
E) Rainfall was recorded by a gauge on each probe which fed into Crop Manager
F) Comparison of actual Yield and quality data against estimations in yield prediction models.

KEY MESSAGES:

- With the current climate trending to decreased seasonal rainfall, each 1% increase in productivity is important.
- Increases in productivity can come from increased yield, more efficient application of inputs, or more timely grain marketing.
- Knowledge on the soil water holding properties, the time when the crop is taking up the most water from the soil and the current yield estimation models allows growers to market grain with more confidence pre harvest.
- Tools such as Yield Prophet, iPaddock Yield, soil moisture Probes and water use efficiency models are all very useful in assisting to predict grain yields with a relatively high level of confidence when accurately set up.
- In this project "iPaddock Yield" provided the greatest level of accuracy in predicting final grain yield on July 31st 2015. The simple French & Shultz "Broken Stick" model was very close to the accuracy of the ipaddock Yield at 77% & 74% accuracy.
- When there is confidence in the early to mid-season yield prediction combined with accurate soil Nitrogen testing and modeling, there is a greater chance of maximizing profits from applied nitrogen.

PADDOCK PREDICTIONS AND ACTUAL YIELD:

Table 5, Grower estimate of point yield, Yield Prophet estimate, iPaddock and actual point yield

SITE	COSGROVE t/ha	CRIPPS t/ha	MESSINA t/ha	MOROWA AG t/ha
Grower Estimate- 8/6/15	3	2.9	2.4	1.4
Yield Prophet- 3/6/15	1.7	2.5	2	1.8
Yield Prophet- 3/7/15	2.2	2.5	1.3	1.6
Yield Prophet- 14/7/15	1.7	2.1	1	1.4
Yield Prophet- 5/8/15	2.3	2.7	1.5	2.3
Yield Prophet- 27/8/15	2.5	2.9	1.7	2.4
iPaddock- 27/8/15	2.2	2.5	2	1.5
iPaddock- 30/9/15	2.5	2.4	1.5	1.3
iPaddock- 30/10/15	2.1	2.5	1.8	1.2
iPaddock- 16/11/15	2.1	2.5	1.8	1.2
Paddock Average	1.8	2	1.4	2.1
Plot Actual	1.48	3.3	1.71	2.33

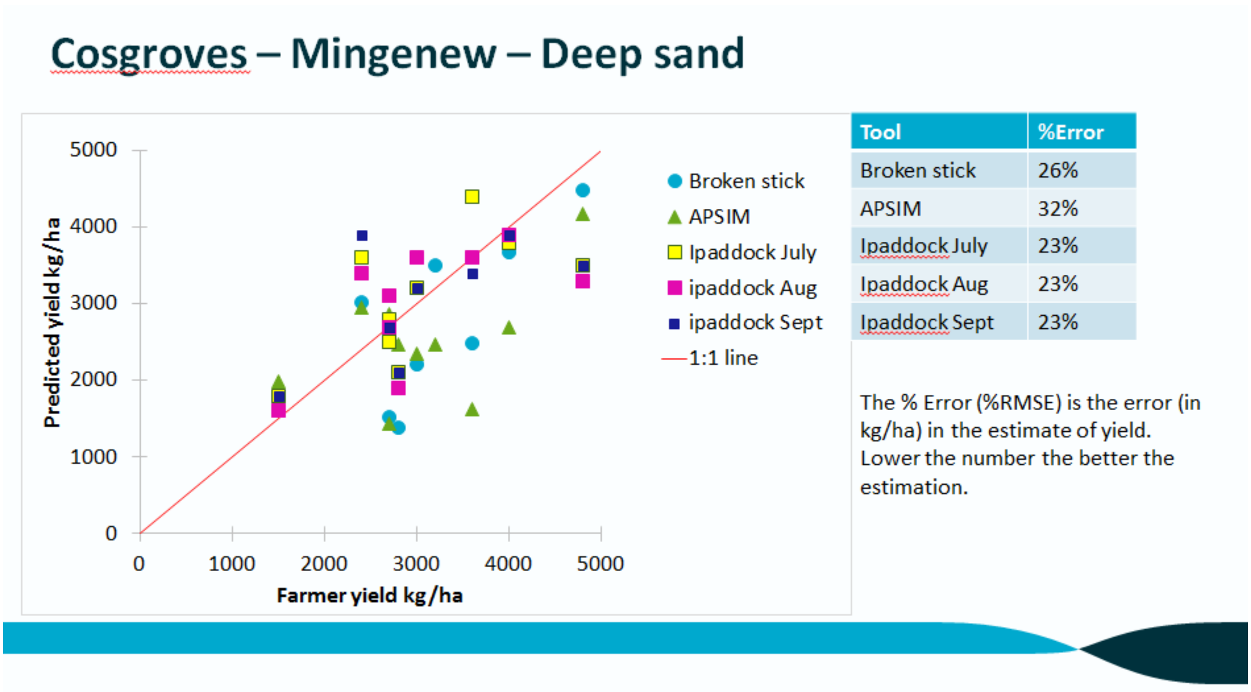

Figure 1. Yield prediction evaluation from Cosgrove Pale Deep Sand soil type, models run retrospectively over previous 10 years of yield and rainfall data.

COMMENT:

iPaddock yield estimated yields along the most consistent line with the smallest % error over the 10 year period.

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Section B. Soil Water Properties

Table 6. Cosgrove, Pale Deep Sand

MEASUREMENT	0-100 mm	100 -200 mm	200-300 mm	300-400 mm	400-500 mm	500-600 mm	600-700 mm	700-800 mm
CLL (mm)	2.38	2.73	2.8	3.29	3.74	6.86	6.86	6.86
DUL (mm)	10.05	10.05	9.69	9.82	10.05	13.08	13.08	13.08
PAWC (mm)	7.67	7.32	6.89	6.53	6.31	6.22	6.22	6.22
Bulk Density (mm)	1.65	1.65	1.66	1.65	1.65	1.65	1.6	1.6
Total PAWC	53.38							
PAW (1/05/2015)	0.5							

Table 7. Cripps, Pale Deep Sand

MEASUREMENT	0-100 mm	100 -200 mm	200-300 mm	300-400 mm	400-500 mm	500-600 mm	600-700 mm	700-800 mm
CLL (mm)	3.27	3.27	8.6	5.85	6.83	7.97	7.97	7.97
DUL (mm)	12.11	13.06	18.16	13.99	14.8	15.33	15.33	15.33
PAWC (mm)	8.84	8.63	9.56	8.14	7.97	7.36	7.36	7.36
Bulk Density (mm)	1.64	1.63	1.57	1.62	1.61	1.61	1.61	1.61
Total PAWC	65.22							
PAW (1/05/2015)	9.03							

Table 8. Messina, Yellow Deep Sand

MEASUREMENT	0-100 mm	100 -200 mm	200-300 mm	300-400 mm	400-500 mm	500-600 mm	600-700 mm	700-800 mm
CLL (mm)	3.07	3.3	4.21	5.11	5.63	7.22	7.22	7.22
DUL (mm)	11.72	11.58	12.26	12.93	13.19	14.27	14.27	14.27
PAWC (mm)	8.65	8.28	8.05	7.82	7.56	7.05	7.05	7.05
Bulk Density (mm)	1.64	1.65	1.64	1.63	1.63	1.61	1.61	1.61
Total PAWC	61.51							
PAW (1/05/2015)	3.52							

Table 9. Morawa Ag, Red Sandy Earth

MEASUREMENT	0-100 mm	100 -200 mm	200-300 mm	300-400 mm	400-500 mm	500-600 mm	600-700 mm	700-800 mm
CLL (mm)	3.99	5.71	4.48	5.43	6.18	5.82	5.82	5.82
DUL (mm)	12.27	14.3	12.15	13.05	13.83	12.27	12.27	12.27
PAWC (mm)	8.28	8.59	7.67	7.62	7.65	6.45	6.45	6.45
Bulk Density (mm)	1.62	1.59	1.62	1.61	1.6	1.62	1.62	1.62
Total PAWC	59.16							
PAW (1/05/2015)	30.57							

SUMMARY:

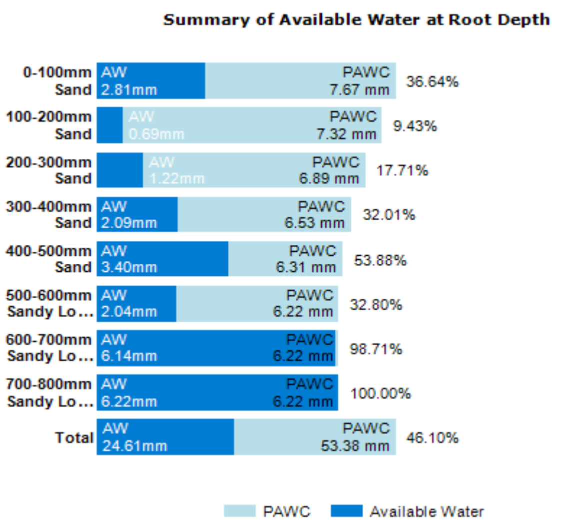
In terms of water bucket size, the Pale Deep Sand at Cosgrove's is the smallest and the Pale Deep Sand at Cripp's is the biggest. Particle size analysis has been used to identify the following limits:

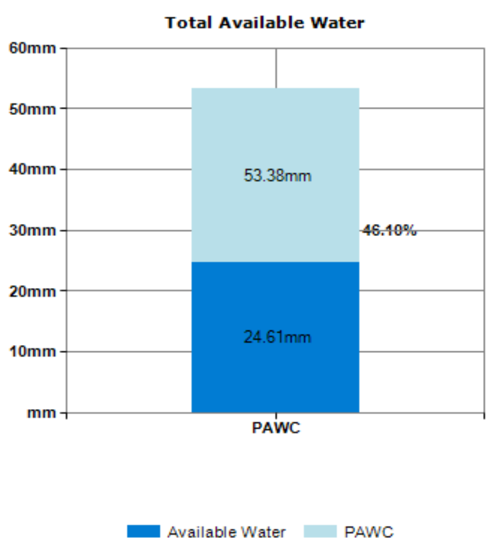
CLL: Crop lower limit - The water content of the soil when the crop has extracted as much water as it can ie: at 10cm the crop will never be able to access the last 2.32mm.

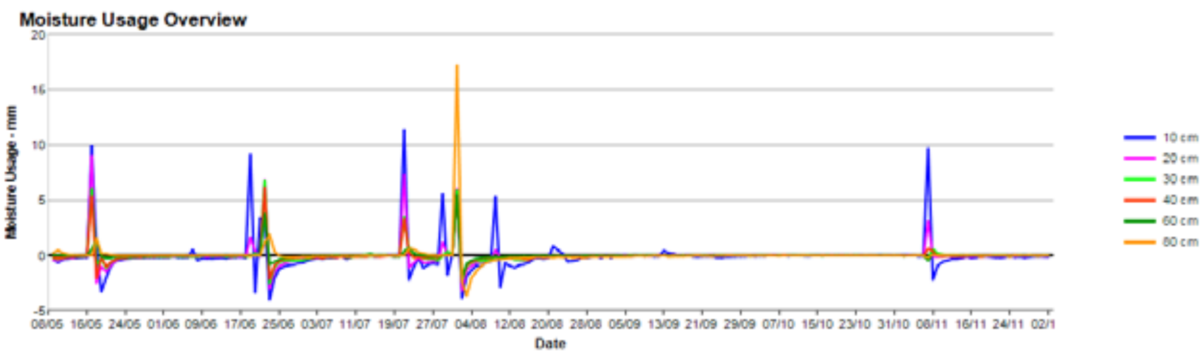
DUL: Drained upper limit – the water content of a soil when it is fully wet but drainage has ceased. PAWC: Plant available water capacity – DUL minus CLL (the amount of water a wheat plant can extract when the profile is full)

The soil water properties (above) have been used in the data interpretation platform "Crop Manager" throughout the season.

Below is an example of this information for Cosgroves on the 30th September 2015. On this date there was 24mm PAW but only 12.25mm available to plant roots – the roots are not getting below 60cm. The figure on the right is termed the "Soil Water Bucket" and displays an increased %of dark blue colour as plant available water increases following a rainfall event.







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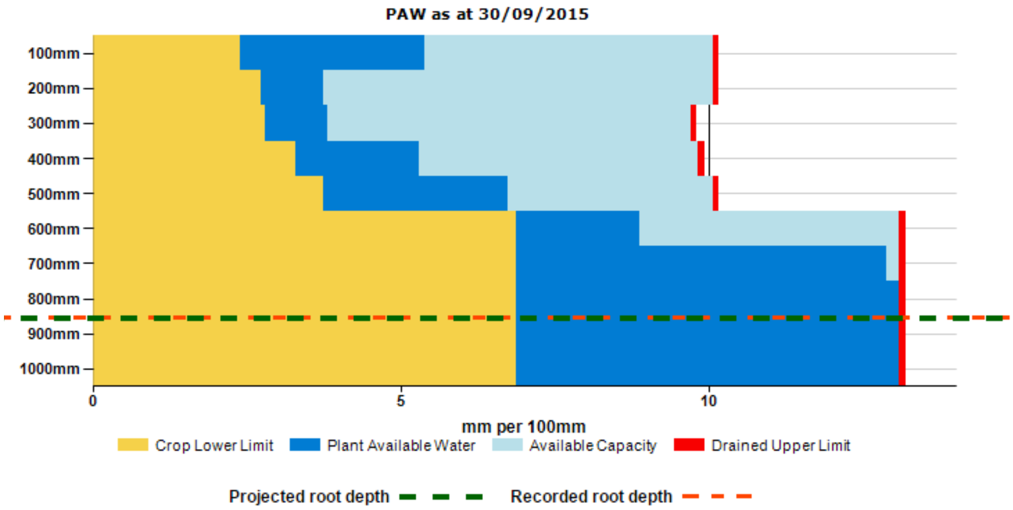

Figure 2. Summary of Available water and the soil water bucket.
Note: Incorrect rooting depth shown, roots are not getting below a depth of 60mm

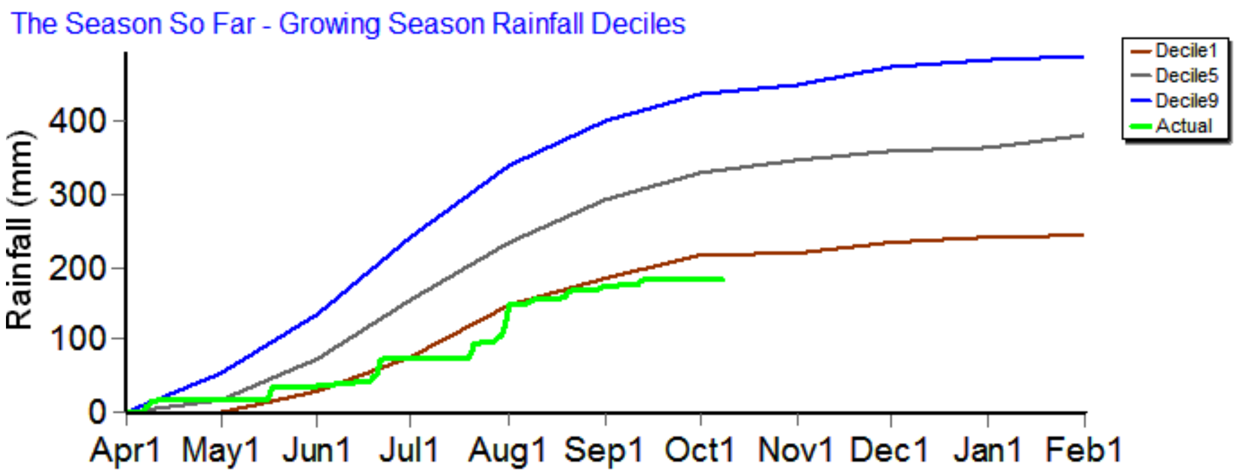

Figure 3. Season rainfall for Cosgrove's

Section C. Evaluation of Nitrogen Usage

Table 1. Cosgrove harvest data and Nitrogen use efficiency

TREATMENT	YIELD t/ha	PROTEIN %	WEIGHT kg/hl	SCREENINGS %	RETURNS $/ha	PARTIAL GM (MINUS N COST)	RECOVERY OF FERTILISER N (%)	PNB (N)
0N	1.44	12.30	77.67	3.52	H2 $433	$433	0	0
20N	1.35	12.60	75.83	3.95	H2 $405	$380	-6.60	0.15
40N	1.40	12.30	77.50	3.88	H2 $422	$371	-1.99	0.08
60N	1.35	12.83	75.43	4.24	H2 $408	$333	-0.94	0.05
80N	1.52	12.83	76.67	3.92	H2 $456	$354	3.81	0.04
100N	1.30	12.7	77.2	3.73	H2 $390	$263	-2.15	0.03
P Value	0.75	0.219	0.425	0.88				
CV%	8.00	0.7	0.7	22.1				
L.S.D 5%	0.33	0.5883	2.768	1.304				

80kg/ha Amsul applied pre seeding across the trial

Table 2. Cripps harvest data and Nitrogen use efficiency

TREATMENT	YIELD t/ha	PROTEIN %	WEIGHT kg/hl	SCREENINGS %	RETURNS $/ha	PARTIAL GM (MINUS N COST)	RECOVERY OF FERTILISER N (%)	PNB (N)
0N	3.36	11.67	80.25	2.36	H2 $1011	$1,011		
20N	3.05	11.60	79.23	2.92	H2 $919	$894	-6.60	0.31
40N	3.25	11.80	79.32	2.43	H2 $978	$927	-1.50	0.17
60N	3.13	11.37	78.94	2.24	APW1 $936	$860	-6.30	0.10
80N	2.74	11.90	79.32	2.02	H2 $824	$722	-11.60	0.07
100N	3.18	11.70	79.28	2.42	H2 $956	$829	-3.60	0.07
P Value	0.38	0.35	0.04	0.11				
CV%	5.80	0.70	0.20	6.70				
L.S.D 5%	0.62	0.51	0.75	0.60				

Table 3. Messina harvest data and Nitrogen use efficiency

TREATMENT	YIELD t/ha	PROTEIN %	WEIGHT kg/hl	SCREENINGS %	RETURNS $/ha	PARTIAL GM (MINUS N COST)	RECOVERY OF FERTILISER N (%)	PNB (N)
0N	1.70	10.47	77.53	6.46	AGP1 $462	$462		
20N	1.74	10.80	77.69	7.34	AGP1 $474	$449	9.00	0.17
40N	1.73	10.93	77.92	7.44	AGP1 $471	$420	4.94	0.08
60N	1.81	11.33	77.12	8.36	AGP1 $493	$418	8.03	0.06
80N	1.89	11.53	78.05	8.56	AUH2 $548	$446	8.80	0.05
100N	1.78	11.87	77.07	7.88	AUH2 $516	$389	5.80	0.04
P Value	0.652	0.001	0.311	0.233				
CV%	7.4	0.2	0.6	8.7				
L.S.D 5%	0.2537	0.5099	1.087	1.88				

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Table 4. Morawa harvest data and Nitrogen use efficiency

TREATMENT	YIELD t/ha	PROTEIN %	WEIGHT kg/hl	SCREENINGS %	RETURNS $/ha	PARTIAL GM (MINUS N COST)	RECOVERY OF FERTILISER N (%)	PNB (N)
0N	2.52	10.33	79.61	8.29	AGP1 $685	$685		
20N	2.63	10.90	78.53	8.64	AGP1 $716	$691	23.00	0.25
40N	2.64	11.37	77.95	8.93	AGP1 $719	$668	18.00	0.13
60N	2.61	11.53	78.01	9.11	AUH2 $758	$683	12.00	0.09
80N	2.63	11.77	77.57	8.5	AUH2 $764	$662	11.00	0.07
100N	2.43	12.17	77.16	8.53	AUH2 $706	$579	6.00	0.05
P Value	0.61	<.001	0.592	0.973				
CV%	7.20	1.8	1.1	24.4				
L.S.D 5%	0.31	0.4104	3.065	2.4				

Price Notes: All prices net delivered Geraldton and GST Exclusive
Recovery of Fertiliser N (%): A measure of the % of Nitrogen recovered from additional fertilizer, 40 – 60% recovery is ideal
PNB (N): Removal to use ratio – quantifies the amount of N being removed in the produce relative to the amount supplied. A PNB less than 0.5, indicates that more N is being applied than is being removed. When PNB is above 1.0, more N is being removed than is being supplied.

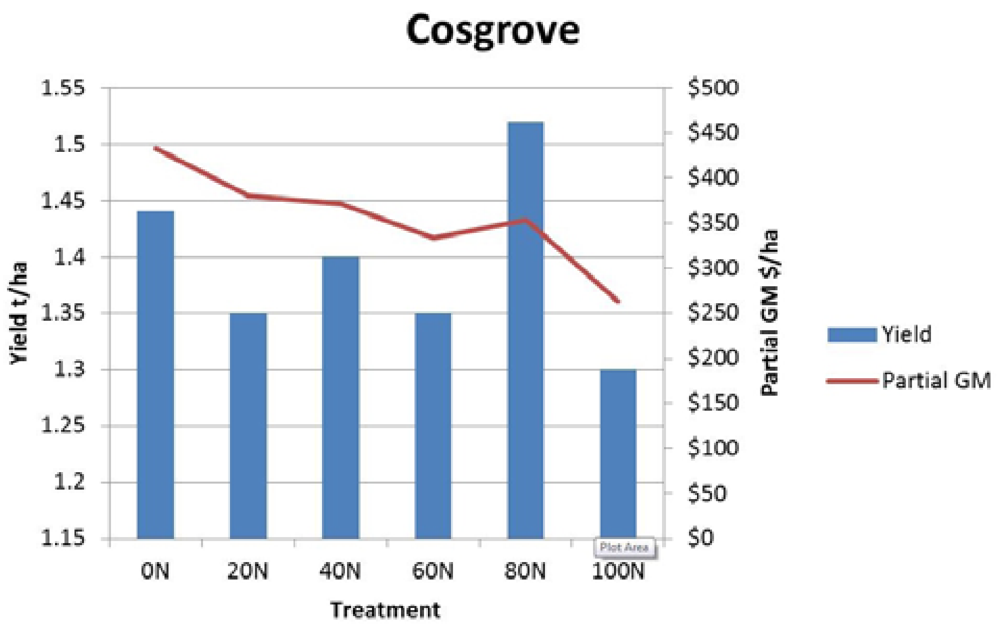

Figure 4: Yield and Partial Gross Margin for the Cosgrove site.

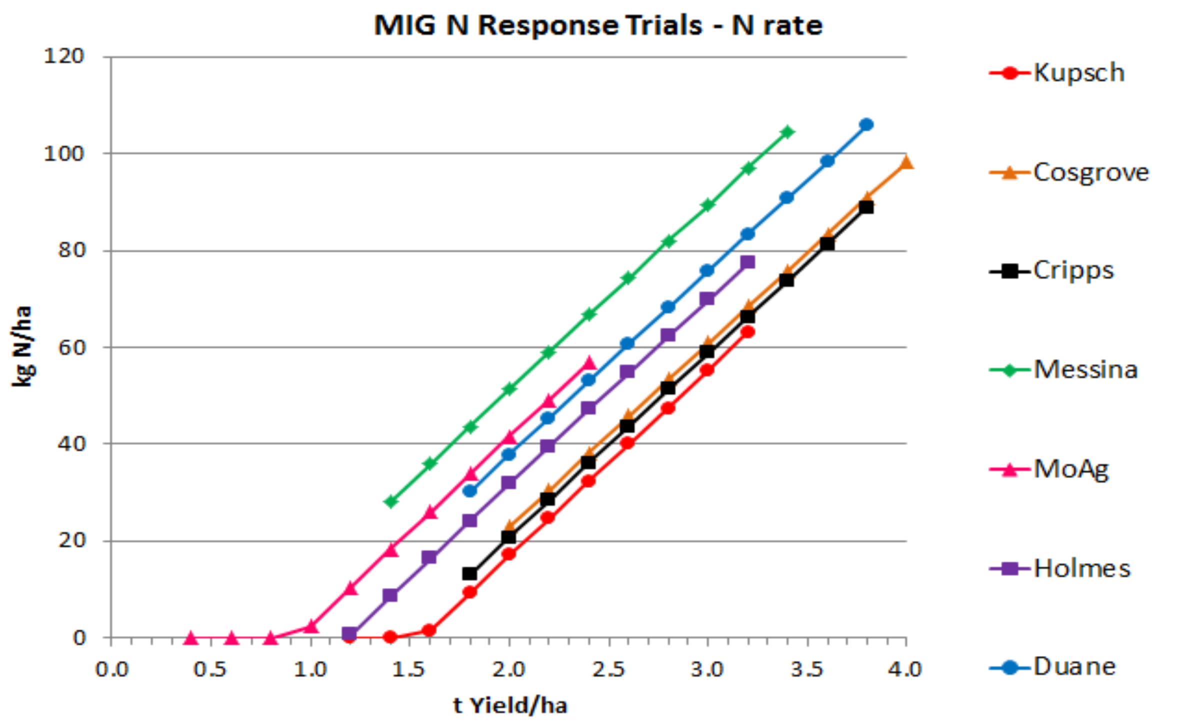

Figure 5: Nitrogen recommendations generated from Equii soil test model, shows the amount of applied soil nitrogen (kg/ ha) required to produce a range of grain yields for a number of sites. N response trials have been used to quantify the nitrogen recommendation

COMMENTS:

- Well below average rainfall (decile 1) at all sites in 2015 resulted in soil moisture, rather than nitrogen supply, being the major limitation to grain yield. The trial was set up to develop a nitrogen response curve with rates from 0 units to 100 units of applied N but in a number of cases soil nitrogen at sowing was adequate and there was little response to applied nitrogen because grain yield was limited by moisture.
- The Cripps soil had the greatest plant available water capacity for wheat plant roots.
- iPaddock yield looks at long term water use efficacy and uses a line of best fit analysis to predict yield based on rainfall received to date and previously achieved yields with a range of soil moisture levels at the same time within the season. Therefore it predicts yield based on actual farmer / paddock performance taking into account current management, soil constraints and rainfall patterns. The more historical yield and rainfall information entered into the model, the greater the accuracy will be. Essentially, past performance is utilized to predict the future yield estimates and in this project, this model, has shown to have the least variation of all models between predicted and actual yield achieved in the paddock.
- The in season nitrogen recommendations shown in the graph above indicated that there was adequate soil N to achieve the following yields: Cosgrove 1.8t/ha, Cripps 1.7t/ha, Messina 1.4t/ha, Morawa Ag 1.0t/ha
- The Equii soil test model utilized within this project indicated that there would be no economic benefit from applied nitrogen until the yield at each site exceeded the figures above.
- The nitrogen recommendation graph generated pre sowing, shown above indicated steep responses to applied nitrogen but

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only if the yield was to exceed the 0N estimate. Note: the Cosgrove site had 19 units of N applied prior to sowing the trial.

- At the time of the post Nitrogen application the following yields were predicted:
  Cosgrove 1.7t/ha, Cripps 2.5t/ha, Messina 2.0t/ha, Morawa Ag 1.8t/ha
- Modeled Nitrogen recommendations for the predicted yield on July 3rd (the time when top up post emergent nitrogen would be applied): Cosgrove 20 units, Cripps 40 units, Messina 55 units, Morawa Ag 30 units.
- The most economic rate of Nitrogen applied at the Cosgrove site was 0 units producing a net return of $433/ ha, the highest yield was achieved at 80 units of applied N but the additional 80kg/ha of yield over the Nil N, was not enough to cover the cost of the extra nitrogen.
- Soil testing pre sowing indicated that there was adequate soil N to produce 2.0t/ha at the Cosgrove site. This shows the importance of deep soil Nitrogen testing to identify how much deep soil N is likely to be available pre sowing and then adjusting the in season nitrogen recommendations accordingly. Because the exact rooting depth and amount of soil N that can be accessed is not always known, an estimate of the amount of soil N that can be utilized is required, the amount of which will vary from season to season depending on the rainfall patterns.
- At the Cripps site 0 units of applied N produced a partial GM of $1011/Ha. Increasing the applied N to 40 units dropped the GM to $927/Ha. There was no yield increase above 0 units of applied N at this site. At sowing, 31 units of soil N was identified in the top 80cm thus restricting the response to applied N with the decile 1 rainfall and very dry hot finish to the season.
- 0 units of applied N was the most profitable at the Messina site returning a GM of $462/ ha with a yield of 1.70t/ha. The 80 units of N treatment was the highest yielding but the additional 190 kg/ha of grain was not enough to cover the cost of the additional nitrogen resulting in a GM of $446/ha.
- At the Morawa Ag College site 20 units of applied N produced a partial GM of $691/Ha, whilst increasing the applied N to 40 units dropped the GM to $668/ Ha as there was no yield increase above 0 units of applied N at this site. At this site 54 units of soil N was identified in the top 80cm at sowing restricting the response to applied N with the decile 1 rainfall and very dry hot finish to the season.
- Maximum N recovery was achieved at 20 units at the Messina and Morawa Ag sites, after this point at each site the additional yield generated from each additional unit of applied N declined. The Cosgrove and Cripps sites had a negative response. The negative response indicates that the plant roots did not access any of the nitrogen applied.
- The point at which maximum N recovery is achieved is not generally the most economic rate to apply N. The point shows that the crop is still very responsive to additional N and this forms the N response curve. The most economic point on this curve will be were the curve flattens out. At this point, additional profit from one extra unit of applied N is equal to two times the value of that unit of applied N.

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