# COGGO Council of Grain Grower Organisations Limited ACN 091 122 039	**Final Report** **COGGO Research Fund for 2014 projects** **A project completion report covering the project. The acceptance of a satisfactory report against the objectives of the project, and agreement on the sharing of any commercial returns and/or IP will trigger payment within 4 weeks, by COGGO for any outstanding payments.**

This Final Report should be completed with reference to the Research and Intellectual Property Agreement (the Research Agreement) signed between the proponent and COGGO Pty Ltd.

1. Project information

Project title	**Yield performance of acid/aluminium tolerant wheat varieties against a new acid tolerant barley Litmus (WABAR2625) across a range of soil acidity profiles via spatial analysis**
Commencement Date	1st January 2014
Completion Date	23rd September 2016

Name of Proponent	Planfarm PTY LTD
ACN/Legal Name or ABN	
Mailing Address	PO Box 2437 Geraldton WA 6530

Administrative Contact	Richard Quinlan
Position	Agronomist
Telephone	0428648828
Fax	0899641142
Email	rquinlan@planfarm.com.au

Project Supervisor/Principal Researcher	Richard Quinlan
Position	Agronomist
Telephone	0428648828
Fax	0899641142
Email	rquinlan@planfarm.com.au

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Project Number	

Date Received	

2. Project results	This section provides a final report against the Project Aim and the Planned Outputs for the Project.

Achievement of the Project Aim	Brief statement of achievement in relation to the aim of the project

Aim: To increase grower profitability by better matching variety and species to soil type and soil pH in Western Australia:

The project aims were achieved in the following ways:

- Typical sandplain paddocks found within the Northern Agricultural Region (NAR) were chosen. These sites had wide ranging soil pH levels both on the surface and at depth. The two sites (Yuna and Mingenew) had complimenting attribute.
- The sites were successfully seeded with wheat and barley varieties with a range of tolerances to soil pH.
- Yield data was successfully collected from all sites and from this data the soil pH test sites were chosen and successfully sampled. The Three Springs site had very high levels of rhizoctonia root rot patches within the trial which made it impossible to compare yield to soil pH. Therefore a pH survey was not done on this site an dinstead extra soil pH samples were taken at the other 2 sites.
- These data layers (soil pH, yield aerial photos and elevation) were then presented to allow comparison between yield and subsoil pH varied across the sites.
- From this data and other data collected at the sites it was shown that:
- Typical yellow sandplain soil in the NAR has widely varying subsoil pH. This spatial subsoil pH varied widely between sites (<30m apart) but varied more widely according to position in the landscape (ie on top of the rises compared to the bottom of the hollows). It was concluded that this variation is driven by historical product removal rather than historical nitrogen leaching).
- The Yuna site had low subsoil pH, but the Mingenew site had lower subsoil pH issues. The Yuna site showed pH rising again at the 30cm depth whereas the Mingenew site had the lowest pH deeper down the profile compared to the Yuna site. It is thought these pH difference between the sites was driving some of the relative yields between varieties contained in the trials. If this is the case then growers need a good understanding of the pH of their soil both at the surface and deeper down the profile if they hope to predict which varieties will perform the best.
- Another factor driving the yield differences of the same variety between the sites is the past rotation. The Mingenew site was sown into lupin stubble compared to the Yuna site was sown into wheat stubbles.
- The differences in the 2 sites and how varieties responded to them was stark. At the Mingenew (lower subsoil pH) site Calingiri was the highest yielding variety whereas at the Yuna site it was the lowest yielding variety.
- The variety Litmus has enhanced tolerance to low subsoil pH. This trait allowed Litmus to be a more robust variety across both soils types, especially where subsoil pH was very low (Mingenew site). However this variety may have yield constraint issues that didn’t allow it to take full advantage of this pH tolerance. Future varieties with these pH tolerant genes may better be able to capture rainfall yield potential.
- At the Mingenew site where subsoil pH was lowest, the variety Calingiri outyielded all other varieties. This variety is widely grown on sandplain soilsin the Mingenew district and this data confirms grower findings. At the Yuna site where subsoil pH was less pronounced and other

varieties were better able to convert moisture into yield.

Project Outputs		Please provide a report on the achievement, or otherwise, of the project outputs as per the planned outputs provided in the Project Proposal.
1	-	Output 1 (from Project proposal) Better appreciation of spatial variability of soil acidity across paddocks and the interaction with commonly grown varieties (Wyalkatchem, Mace, Calingiri, Hindmarsh and Litmus).
		Comment: The project allowed for one of the most intensive paddock scale pH surveys to be performed in Western Australia. This showed that pH varied significantly between sites and correlated well with the position of the test site in the landscape (ie bottom of a hollow compared with the top of the ridges). When this was related to spatial yield for each variety across the paddock a thorough analysis of varietal yield and pH was able to be carried out. This concluded that although pH is an important driver of yield, the most important factors are soil moisture holding capacity and nutrition. It was concluded that the interactions between all of these factors is required to fully understand varietal performance across a paddock.
2	-	Output 2 (from Project proposal) Development of thresholds at which key varieties lose competitiveness due to soil acidity.
		Comment: No hard and fast thresholds could be established for each variety from the data collected however the wheat variety Calingiri performed well where soil pH was the lowest and the deepest, whereas the variety Litmus was the best performed the best performing barley variety under these conditions. It was suggested that where the pH is low (<4.5) and deeper down the profile (such as the Mingenew site) then the constraints imposed by soil pH are more pronounced and have a greater influence on pH sensitive varieties such as Hindmarsh. Litmus on the other hand had a more robust performance under these pH constraints. Other monitoring within the project show Litmus to be able to extract moisture from acid profiles and produce more biomass than varieties such as Hindmarsh. It was able to convert these traits into yield suggesting if these pH tolerant traits were to be bred into better performing varieties then they would had wide spread appeal to wheat growers in the NAR.
3	-	Output 3 (from Project proposal) Lupins are becoming less appealing to grow in rotation with wheat due to poor weed control, poor yields and gross margin issues.
		Comment: Although there was not a direct gross comparison made between lupins and barley, this work has shown that barley can yield significantly better than wheat and product a better gross margin than wheat in the right paddock and therefore should be considered as an alternative rotation to wheat on wheat. To determine where barley is likely to perform then subsoil pH needs to be fully investigated.

Project results	Please provide brief statements on the results of the Project

This section should cover aspects identified in *Section 7.3* of the Research Agreement

- the results of the Project, including discoveries made and other achievements (including any Project IP and Project Confidential Information);
- the potential application of the outputs of the Project to the Western Australian grains industry and broader community;
- the actual or potential economic benefits flowing to the Western Australian grains industry and broader community from the Project;
- the difficulties encountered;
- the conclusions reached;
- the Researcher's recommendations for any further research;
- a list of scientific papers or publications resulting from the Project; and
- attach copies of any photos, diagrams or other artworks (including, if requested by COGGO, negatives, bromides or the like) which the Researcher has and which may be of assistance to COGGO in the dissemination of information concerning the Project to COGGO's stakeholders.

Summary:

An in depth spatial analysis study was performed on 3 sandplain sites (Yuna, Mingenew and Three Springs) in the NAR of Western Australia looking at better matching soil pH to variety. The project compared how the relative yield of 5 varieties (Hindmarsh, Scope, Litmus, Wyalkatchem, Calingiri, Mace) changed their relative yield as the soil pH changed.

The project sites had wide ranging soil pH levels both in the surface (0-10cm) and at depth (20-30cm). All three sites have had lime applications over the past 10 years and therefore the topsoil pH was significantly higher than the subsoil pH. The soil pH across the study paddocks was highly variable spatially even across small distances (30m) in the grid surveys conducted. This variability was most pronounced at the Yuna site. The soil pH was also correlated with position in the landscape and was the opposite for the Yuna and Mingenew sites. At the Mingenew site the lowest subsoil pH occurred in the high yielding hollows compared to the Yuna site where the lowest subsoil pH occurred on the low yielding ridges.

The Three Springs site had significant rhizoctonia bare patch infection throughout the paddock which made the correlation with soil pH impossible. For this reason this site was abandoned and extra sampling was done at the other two sites.

Visually the soils at the two sites looked similar however the relative yields of the varieties tested changed significantly between sites. This highlights the need for growers understand the soils they are dealing with to better match soil pH and variety/species.

Litmus Performance:

All three sites showed Litmus to have a higher numerical reading for NDVI (Normalised Difference Vegetative Index) compared to all other wheat and barley varieties in the trial. However final yields were lower than the best performing variety at both sites.

At the Yuna site a soil profile study was carried out under the Hindmarsh and Litmus treatments. This study tested soil pH and moisture content down the profile during (21st August) the 2014 season. This showed the profile to be acidic at depth and at its lowest at the 20-30cm depth. Litmus was able to extract significantly more soil moisture at depth compared to Hindmarsh up to this time. It was concluded that this difference in moisture extraction was due to the improved pH tolerance of Litmus.

The above 2 observations suggest that although Litmus is better suited to acidic profiles than other varieties in the project, there must be other yield limiting traits of the variety that inhibit it from converting this advantage into grain yield.

Correlations between pH and variety performance:

Two methods were used to compare varietal performance with soil pH. The showed that although soil pH is important and limiting yield it is still not the most important driver of yield. Soil qualities such as water holding capacity and nutrition

Method 1: Varietal analysis along a transect comparing two different soil types:

- At Yuna the highest yielding variety was Hindmarsh. This variety also resulted in the highest gross margin compared to other varieties tested. Litmus failed to outyield Hindmarsh even on the more acidic section of the paddock. Calingiri was the lowest yielding variety which was the opposite compared to the Mingenew site. Wheat performed relatively better on the stronger soil types in the paddock.
- At Mingenew, Calingiri was the highest yielding variety and produced the highest gross margin. The highest yielding barley variety was litmus which outyielded Hindmarsh by 390kg/ha. There were no stark differences in how varieties yielded relative to each other along the transect as pH and soil type changed.

Method 2: Varietal analysis around each soil test site:

- There was a poor correlation between soil pH and varietal yield at both trial sites. This suggests that factors such as water holding capacity and nutrition are driving yield even though the pH of these better quality soils is low.

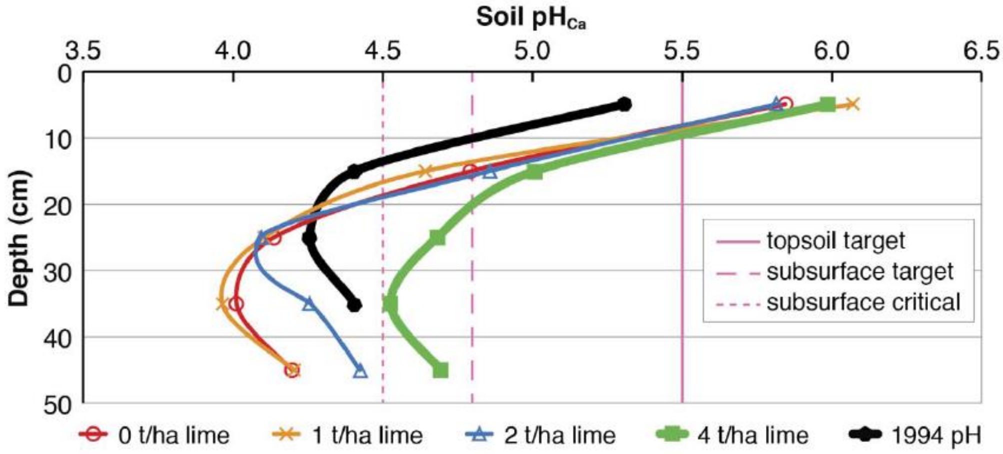
Background:

Growers in the eastern, central and northern wheatbelt of Western Australia are losing rotational options due to dry seasons, associated frost and weed control issues. Dry seasons mean growers need to better utilize stored soil moisture when growing crops to extract the best returns.
Soil acidity is seriously affecting the ability of crops to use subsoil moisture reserves. Soil acidity affects two-thirds of Western Australia's wheat belt and costs broadacre agriculture in excess of $70 million annually through lost production (DAFWA 2006). As a result growers are looking for a range of tools to manage this constraint. Most farmers have adopted a liming program and whilst effective in the long term, full benefits are often not realized immediately. There is a need for growers to have more rotational options on soils with critical pH issues.

The Northern Agricultural region contains large areas of yellow sandplain soils. They differ from southern sandplain soil in the depth down to a duplex layer. In the south the depth of the duplex layer of clay or gravel is 10-40cm, whereas in the north, the duplex zone is between 30cm to several metres.

The NAR yellow sandplain soils are only mildly acidic (pH 5.5 throughout the profile) in the natural state. However they have several characteristics mean that under intensive agriculture they develop soil pH issues over time:

- They are highly productive soils have had high levels of product removal over decades of agriculture. This has removed alkalinity and has been the major cause of acidity on these soils.
- The low CEC of these soils has resulted in a poor ability to buffer these pH changes.
- These soils all contain high levels of iron and aluminium oxides. It is these oxides that give these soils their charactistic yellow brown colour. The aluminium oxides become exponentially more soluble when soil pH falls below pH 4.7 and is responsible for most of the negative crop effects of low pH.
- Leaching of applied nitrogen as well as legume production on these soils have also been significant sources of acidification.
- The leaching issues and rainfall have meant soil acidity has moved down the profile with time (Figure A).



(Figure A): Soil pH profiles in 3013 for different lime treatments compared to the starting pH 20 years earlier. In addition to the lime treatment applied to the trial, the paddock and trial has received 4 blanket applications of 1t/ha lime in 1998, 1999, 2003 and 2012). The trial was located on typical yellow sandplain soil found in the Northern Agricultural Region (NAR) of Western Australia. Note that over time the pH has moved deeper and pH has become more acidic. The pH level below which crop root growth is compromised is marked by purple lines on the chart.

Barley handles frost better than wheat, grows well after wheat and is one of the best crops other that wheat at extracting subsoil moisture as long as pH is not an issue. For many regions in Western Australia the ability to grow barley is likely to improve returns and the robustness of rotations. However soil acidity is affecting barley yields and is thought to be one of the reasons why barley performs poorly with respect to wheat on sandplain soils in the north.
Wheat is inherently more tolerant of low soil pH. Growers have had access to a number of wheat varieties which possess good tolerance to acidic soils and through our National Variety Testing (NVT) on these soils we have been inadvertently selecting varieties tolerant to low pH. However there has been no acid soil tolerant barley varieties released.

A new line of barley called Litmus (WABAR2625) is likely change barley tolerance to soil acidity. Australian wheat and barley breeding company InterGrain considers acid soil tolerance as a barley breeding priority. Litmus is the first commercially available variety with a soil acidity trait and as such there is a need to fully evaluate this variety compared to other wheat and barley varieties on a range of soil types.
Initial large scale evaluations are promising. In 2011 in a Mingenew Irwin Group Demonstration on acid soil showed Litmus out-yielded the next highest barley variety (Buloke) by 800kg/ha and out-yielded Wyalkatchem by 1.46t/ha.

Project objectives and methods:
The objective of this project is to determine if the variety Litmus with acidity tolerance has a relative yield advantage where soil pH is low compared to other varieties of wheat and barley commonly grown in the region. The project established 3 trial sites in the Northern Agricultural Region (NAR) of Western Australia that were intensively sampled. The following methodology was used allow for pH tolerance comparisons between varieties:

- The sites that were selected were likely to have a high variation in soil pH.
- Variety trials were laid down in the three project paddocks.
- NDVI surveying was done (July) to add to the yield data and act as a backup in case of frost or in case yield data information at harvest was lost due to computer failure.
- Soil pH and moisture comparisons were collected down the profile under the Litmus and Hindmarsh plots via a soil pit dug in August to assess root access to moisture differences between these varieties.

- Yield data was collected and areas where the relative yield of Litmus changed compared to other varieties was noted. Raw yield data was collected from the header and yield anomalies cleaned.
- The soil pH of the project paddocks was grid surveyed across the areas of the paddock most likely to contain large soil
- Yield and elevation maps and soil pH down the profile were compared in the following ways.
    - **Method 1: Varietal analysis comparing two different soil types:** Distinct zones were identified within the trial sites. These zones were selected to have contrasting soil pH (high and low). The grain yields for each variety from these high and low pH areas were compared. These comparisons allowed us to determine what soil type and soil pH best suited the varieties within the project
    - **Method 2: Varietal analysis around each soil test site:** Yield data was collected in a 40m radius around each pH sample site for each variety. A correlation was performed to determine a link, if any, existed between soil pH and yield.

(Table 1). Project paddock information for the three trial sites (Yuna, Mingenew and Three Springs)

	Yuna (Greens)	Mingenew (Greaves)	Three Springs (Eva)
Soil Type	Strong Yelllow Sandy Loam in the hollows and slightly weaker sand on the ridges.	Strong Yelllow Sandy Loam in the hollows and slightly weaker sands on the ridges.	Strong Yellow sands with gravelly sand on the ridges.
Rotation	2013 – Wheat, 2012- Lupins	2013 – Lupins, 2012 - Wheat	
Varieties	Calingiri, Mace, Litmus, Hindmarsh, Scope	Wyalkatchem, Calingiri, Mace, Litmus, Hindmarsh.	Calingiri, Mace, Cobra, Litmus, Scope, Hindmarsh
Time of sowing	9th May 2014	12th May 2014	19th May 2014
Barley Seeding Rate	65kg/ha	65kg/ha	60kg/ha
Wheat Seeding Rate	80kg/ha	80kg/ha	80kg/ha
Seeding Fertiliser	80 kg/ha Macro Pro + 50 L/ha Flexi N + Zn	100 kg/ha Agras Extra	75 kg/ha MAP/MOP (67:33 blend) + 50 L/ha UAN
Trial design	Common Plot design with Scope the common plot	Common Plot design with Wyalkatchem the common plot.	Demonstration Design
Adjusted Yield Data	Mace – 2.15 t/ha Calingiri – 1.80t/ha Scope – 2.52 t/ha Hindmarsh – 3.03 t/ha Litmus – 2.71 t/ha	Wyalkatchem – 2.99 t/ha Litmus – 3.17t/ha Hindmarsh – 2.78 t/ha Mace – 3.09 t/ha Calingiri – 3.31 t/ha	

(Table 2): Rainfall data for the project paddocks at Yuna, Mingenew, and Three Springs. The 2014 Season has been dry to date which is likely to exacerbate the differences between pH tolerant and intolerant varieties in the project.

Year	Month	Yuna	Mingenew	Three Springs
2013	October	17	19	14
2013	November	0	2	0
2013	December	0	1	0
2014	January	3	10	12
2014	February	1	1	10
2014	March	1	9	20
2014	April	49	41	35
2014	May	63	53	54
2014	June	15	36	31
2014	July	36	59	37
2014	August	11	22	33
2014	September	52	60	59
2014	October	4	16	6
2014	November	1	20	7
2014	December	2	0	0
Total		**255**	**349**	**318**
Calender		**238**	**327**	**304**
GSR		**230**	**287**	**255**
Effective		**142.1**	**179.4**	**167.2**

YUNA TRIAL SITE:

Summary of soils and soil pH found at the Yuna trial site:

- The natural soil pH of these soils tends to be 5.5-6.0 throughout the profile. This soil profile is less acidic at depth than the Mingenew site. The trial site has had lime applied in the last 5 years which is beginning to move down through the soil profile due to cultivation and leaching.
- Soil pH varied significantly across the soil types contained within this trial site (Table 4).
- 174 pH samples were taken from 58 pH sites across the trial paddock to gain insight into how and where the soil pH varied across the trial paddock. Soil pH characteristics at the Yuna site are contained in (Table 3) below as well as individual pH results in Appendix !.
- Grain yields tend to be highest in the hollows and lowest on the ridges. Typically the soils are better quality yellow sandy loams in the hollows with better water holding capacity. The ridges consist of weaker yellow sands with lower water holding capacity. They have had wind erosion events in their past.
- Agricultural product removal and nitrogen fertiliser leaching has resulted in soil pH’s to fall, but not to the extent of the Mingenew site.
- pH is highest in the topsoil due to previous lime applications. These lime applications are still making their way down the profile.
- pH decreases with depth. pH tends to be lowest at the 10-20cm depth and increasing slightly at the 20-30cm depth although not at every site is the 10-20cm layer the lowest pH. The Mingenew site has its lowest pH levels in the 20-30cm layer.
- pH is more variable at this site than at the Mingenew site.

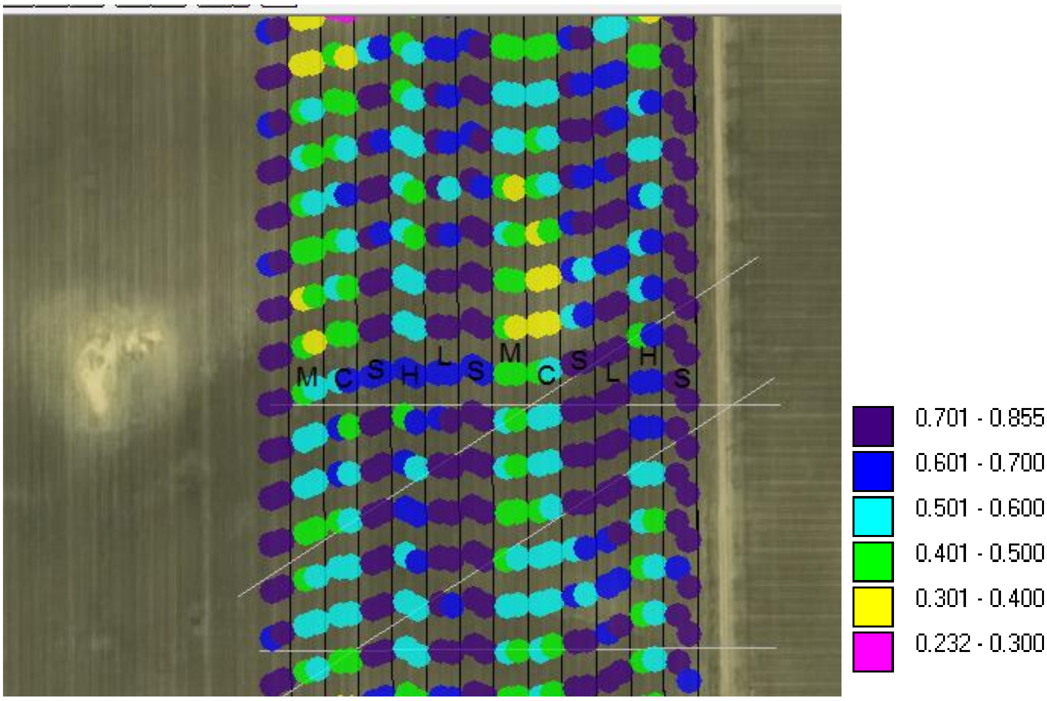
- pH is generally lower on the ridges compared to the hollows especially at depth. This is the opposite of the Mingenew site.
- Yield in the hollows was highest due to better quality soils with greater water holding capacity.

(Table 3): Yuna. Soil pH characteristics of the trial site.

	0-10cm	10-20cm	20-30cm
Average Soil pH	5.0	4.6	4.7
pH Range	4.3-6.0	3.6-5.8	3.5-5.9
pH in Hollows (280.6 - 285.1)	5	4.8	4.9
pH on Ridges (287.8 - 293.2m)	5.2	4.6	4.5

NDVI Measurements:

The Yuna site was measured for relative biomass (NDVI) using the Greenseeker technology (17th July 2014). Litmus Barley at this stage of growth had significantly higher biomass compared to other treatments (Figure B).



(Figure B): Yuna. Biomass (NDVI) measurement. Note the variety order in the picture.(M=Mace, Calingiri, Scope, Hindmarsh, Litmus). Note Litmus and scope having the highest biomass levels throughout the trial compared to Mace, Calingiri and Hindmarsh.

Soil moisture and soil pH under Litmus and Hindmarsh (21st August 2014) (Yuna):

In August a soil pit was dug at the Yuna site in the Litmus and Hindmarsh varieties and differences between the moisture levels still remaining in the profile were measured. A theta moisture probe was used to measure moisture at 10cm increments down the profile (Figure C). Measurements were made on a volume/volume basis and converted into mm of effective rainfall basis (Table 4). Soil samples were taken for pH testing and are displayed in (Table 4). It was assumed that %moisture less than 1.2% was unusable by the crop and was netted off the yield calculations contained in (Table 4).

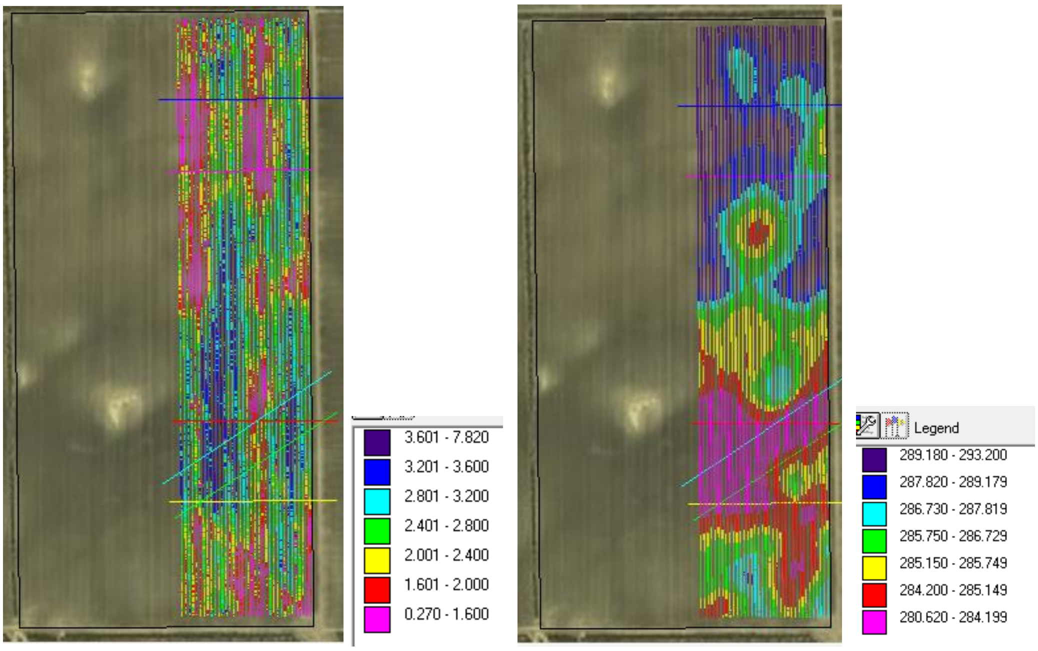
- The Litmus soil profile was dryer to a greater depth compared to the Hindmarsh treatment.
- At the time of sampling there was 60mm of effective rainfall stored below the Hindmarsh (to 1.60m) plot and 42mm of effective rainfall below the Litmus plot. Converting this to a potential yield basis, Litmus should have already set 302 kg/ha (at 16kg/mm RYP (Rainfall Yield

Potential)) more yield potential than Hindmarsh. However yield data from yield maps around the soil pit site show the two varieties yielding the same. This may highlight the better yield potential of Hindmarsh even though it can't access as much moisture down the profile.

(Figure C): Moisture measurements taken using a Theta Probe. YFIG field day 19 August 2014. Approximately 50 growers discussing the COGGO Litmus project and soil pH.

(Table 4): Yuna. Moisture measurements (21st August 2014) using a Theta probe and converted to mm of effective rainfall below each variety. For yield calculations it was assumed moisture content below 1.2mm/10cm were unusable by the crop. At 16kg/mm RYP this equates to 302kg/ha more yield potential already fixed by Litmus compared to Hindmarsh. However grain yield at this site from yield map data show the two varieties yielding the same.

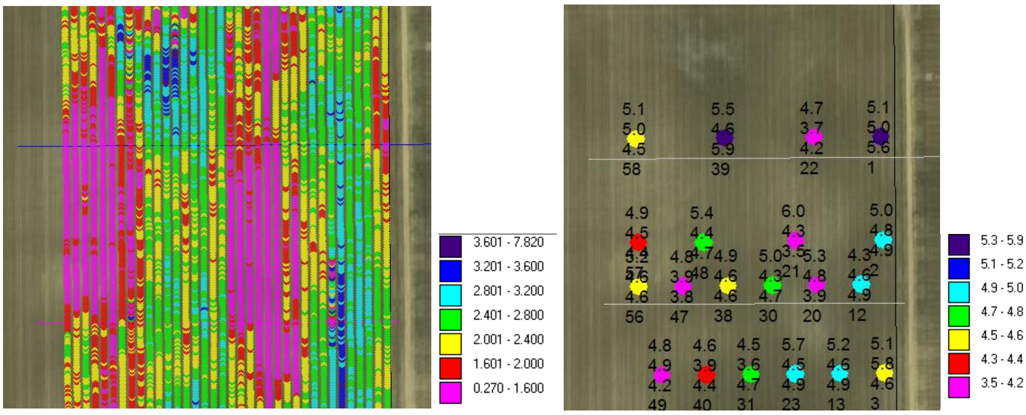
21st August	**Hindmarsh**		**Litmus**		**pH CaCl**	**Extra moisture Extracted by Litmus**	
Depth	**Moisture (mm/10cm)**	**Yield (kg/10cm)**	**Moisture (mm/10cm)**	**Yield (kg/10cm)**		**Moisture (mm/10cm)**	**Yield (kg/10cm)**
0-10	2.3	17	2.3	17	**4.9**	0.0	0
10-20	2.6	23	2.6	23	**4.2**	0.0	0
20-30	1.8	10	1.6	7	**4.3**	0.2	3
30-40	1.9	12	2.0	0	**4.7**	0.0	12
40-50	1.9	12	1.5	5	**4.7**	0.4	7
50-60	2.3	18	1.5	5	**5.0**	0.8	13
60-70	3.0	28	1.8	9	**5.2**	1.2	19
70-80	3.5	37	2.1	14	**5.3**	1.4	23
80-90	3.2	32	2.4	19	**5.3**	0.9	14
90-100	3.6	39	2.3	18	**5.1**	1.3	21
100-110	4.5	53	2.9	27	**5.4**	1.6	26
110-120	5.1	62	3.0	29	**5.3**	2.1	33
120-130	5.4	68	3.7	40	**5.5**	1.7	27
130-140	5.5	69	3.3	34	**5.2**	2.2	36
140-150	6.4	84	4.1	46	**5.3**	2.4	38
150-160	6.9	92	5.0	61	**5.5**	1.9	30
Total	60 mm	654 kg/ha	42.0mm	352 kg/ha	**Total**	18.1mm	302kg/ha
Yield from Yield Maps		2.66t/ha		2.7 t/ha			



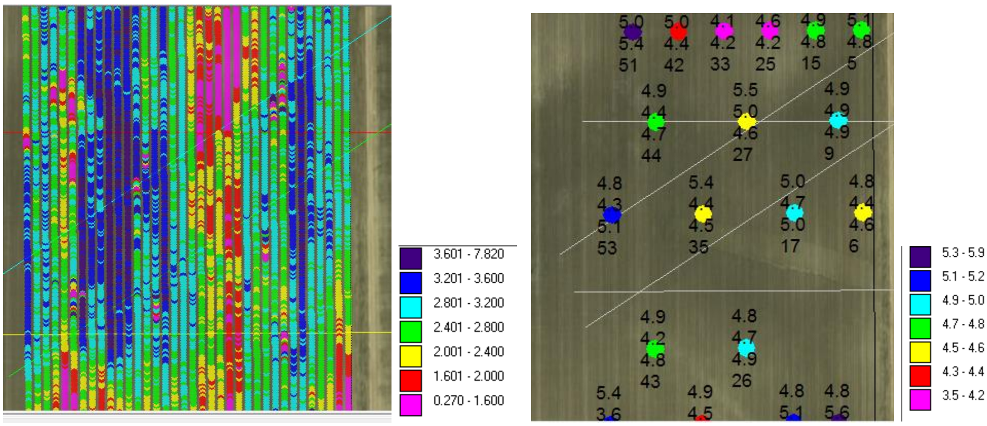
(Figure D): Yuna. Paddock yield (Left) and elevation (Right). Typical of this region there are stronger yellow sandy loam soils in the hollows and weaker yellow sands on the ridges. The tops of the ridges have been eroded by wind in the past as can be seen by lighter areas on aerial photo.

Method 1: Varietal analysis along a transect comparing two different soil types:

- All barley varieties outyielded wheat varieties at this site even where soil pH was likely to have affected barley root growth (ie the northern transect) more than wheat root growth. This may have been related to the paddock being in wheat in the 2013 season.
- Hindmarsh was the highest yielding variety along the complete transect. . It outyielded all varieties in the trial on both the good and poor soil types, however the yield advantage in the good soil type was reduced (See Table 5 &6).
- Comparing the gross margin of wheat and barley in this trial and assuming similar input costs Hindmarsh grossed $757/ha ($250/t) compared to Mace at $645/ha ($300/t). This means hindmarsh was a more profitable rotation for this paddock in 2014.
- Litmus failed to outyield Hindmarsh even on the weaker more acidic soil type. Relative yield didn't change between Litmus and Hindmarsh for the 2 different soil types
- Scope was the lowest yielding barley variety. Scope yielded relatively better compared to Hindmarsh and Litmus on the stronger soil type.
- Wheat varieties performed better compared to barley varieties on the stronger soils.
- Mace was the highest yielding wheat variety.
- Calingiri was the lowest yielding treatment overall which is the opposite of the Mingenew site, It performed relatively better on the good soil type.



(Figure E): Yuna: Location of northern transect (poor site)l for yield (t/ha) and soil pH data is presented in (Table 5) below.



(Figure F): Location of Southern transect (Good site) for yield (t/ha) and soil pH data is presented in (Table 5) below.

(Table 5): Yuna: Adjusted Yield data (common plot design) and soil pH data extracted from yield maps for the two selected soil sites (Figure E & F). Normalised yields was used in this comparison to remove the yield advantage of some varieties. This allows for better comparison between varieties to assess where each variety has a competitive advantage. Note the average of the full transect may not equal the average of the northern and southern transects.

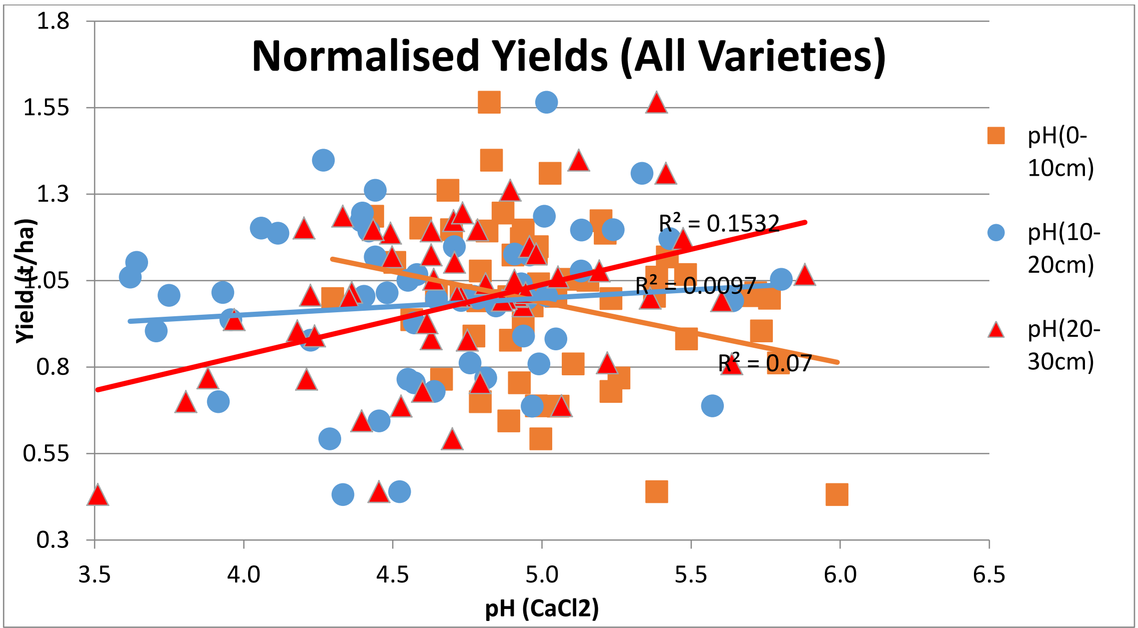
Treatment	Adjusted Yield (t/ha) (Common Plot Design)	Yield (% Scope)	Normalised Yield	Normalised Yield (% Scope)	Average pH (CaCl) (0-10cm, 10-20cm, 20-30cm)
Full Transect					
Mace	2.15	85%	0.98	96%	5.0, 4.6, 4.7
Calingiri	1.80	72%	0.99	97%	5.0, 4.75, 4.65
Scope	2.52	100%	1.00	100%	5.0, 4.57, 4.68
Hindmarsh	3.03	120%	1.05	104%	5.1, 4.75, 4.85
Litmus	2.71	108%	1.00	98%	5.1, 4.8, 4.9
Northern Transect, Poor Site(Low Yield Potential, more acidic at depth)					
Mace	1.47	69%	0.67	78%	5.1, 4.5, 4.4
Calingiri	1.26	59%	0.69	80%	5.1, 4.5, 4.4
Scope	2.14	100%	0.86	100%	5.1, 4.5, 4.4
Hindmarsh	3.01	140%	1.05	121%	5.1, 4.5, 4.4
Litmus	2.51	117%	0.92	107%	5.1, 4.5, 4.4
Southern Transect, Good Site(High Yield Potential, less acidic at depth)					
Mace	2.46	80%	1.12	91%	5.0,4.5, 4.8
Calingiri	2.23	73%	1.22	98%	5.0,4.5, 4.8
Scope	3.07	100%	1.24	100%	5.0,4.5, 4.8
Hindmarsh	3.49	114%	1.21	98%	5.0,4.5, 4.8
Litmus	2.88	94%	1.06	86%	5.0,4.5, 4.8

(Table 6) Yuna: Relative yields of wheat and barley varieties on the selected soil types.

	Yield t/ha	Soil pH (0-10cm, 10-20cm, 20-30cm)	cf Calingiri	cf Mace	cf Hindmarsh	cf Litmus	cf Scope
Northern Transect Good Soil (Low Yield Potential, more acidic at depth)							
Mace	1.47	5.1,4.5, 4.4	116%	100%	49%	59%	69%
Calingiri	1.26		100%	86%	42%	50%	59%
Scope	2.14		170%	146%	71%	85%	100%
Hindmarsh	3.01		238%	204%	100%	120%	140%
Litmus	2.51		198%	170%	83%	100%	117%
Southern Transect Poor Soil (High Yield Potential, less acidic at depth)							
Mace	2.46	5.0,4.5,4.8	108%	100%	71%	86%	80%
Calingiri	2.23		100%	92%	64%	79%	73%
Scope	3.07		127%	120%	88%	106%	100%
Hindmarsh	3.49		141%	133%	100%	120%	114%
Litmus	2.88		121%	114%	83%	100%	94%

Method 2: Varietal analysis around each soil test site:

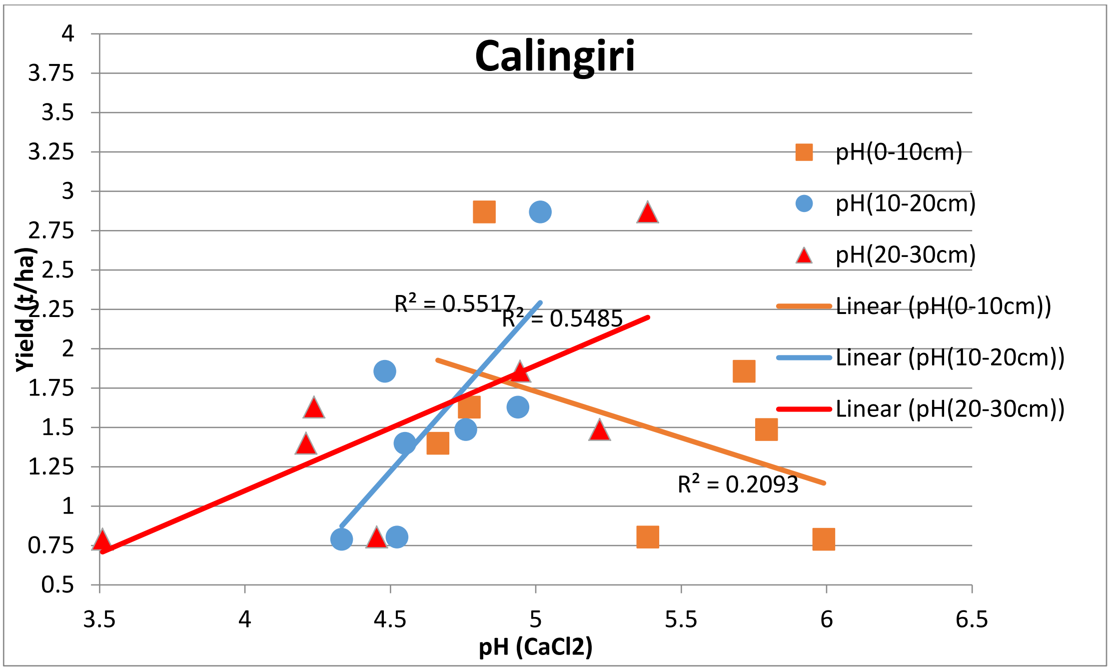
Around each soil pH test site (40m diameter) the yield data was averaged and presented below. The yield data for each variety was normalised according to each varieties plot average. See raw data in (Appendix I).



(Figure G): Yuna: Normalised yields in a 40m diameter around each soil pH test site. Yields were normalised to the average yield for each variety. Overall there was no correlation between soil pH and yield.

There was a poor correlation between soil pH and yield for the various varieties (Figure G). The best correlation between pH and yield was achieved in the Calingiri treatment (Figure H). Note the following observations from this data:

- The best correlation (R^2=0.55) between yield and pH occurred with Calingiri at the 10-20cm and 20-30cm depth. Higher pH measured at this depth resulted in increasing yield.



(Figure H): Yuna: The correlation between Calingiri yield and soil pH. The strongest correlation between yield and pH was at the 10-20cm and 20-30cm depth. At this depth the correlation was positive (ie as pH increased the yield increased).

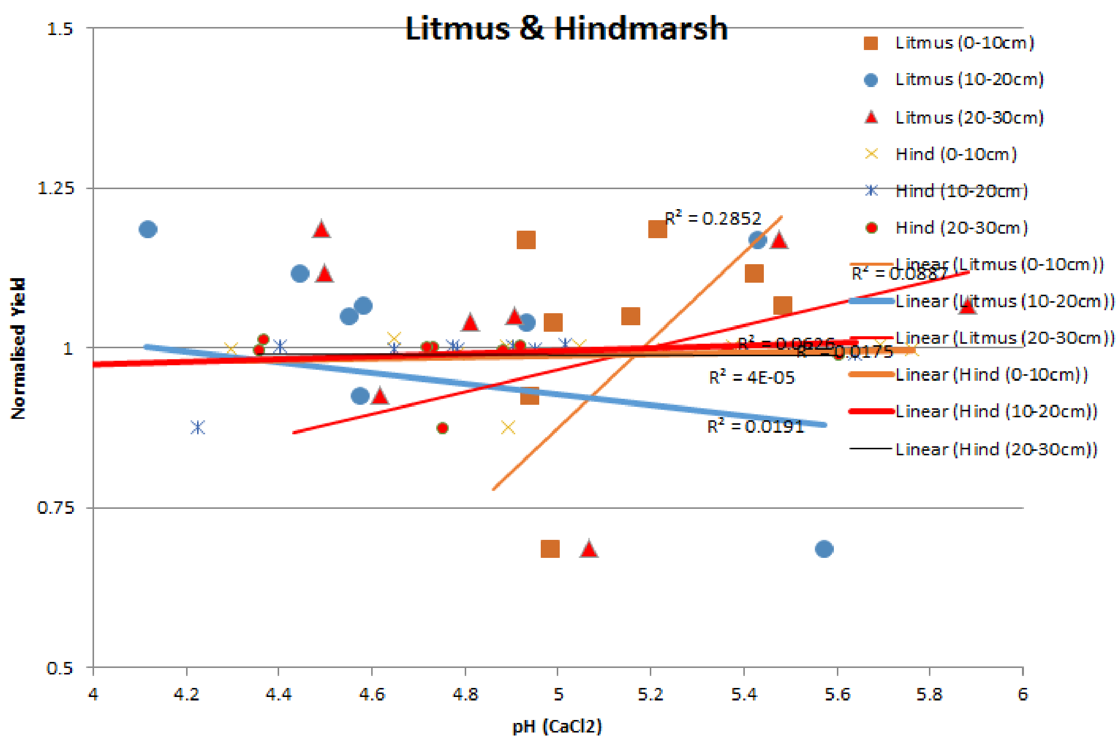


Figure I): Yuna: Litmus does not appear to tolerate lower pH soils better than Hindmarsh. Or the yield of Litmus and Hindmarsh is not being driven by soil pH at any depth. Rather it is probably being driven by better soils types where the soil pH is low due to product export.

MINGENEW TRIAL SITE:

Summary of soils and soil pH found at the Mingenew trial site:

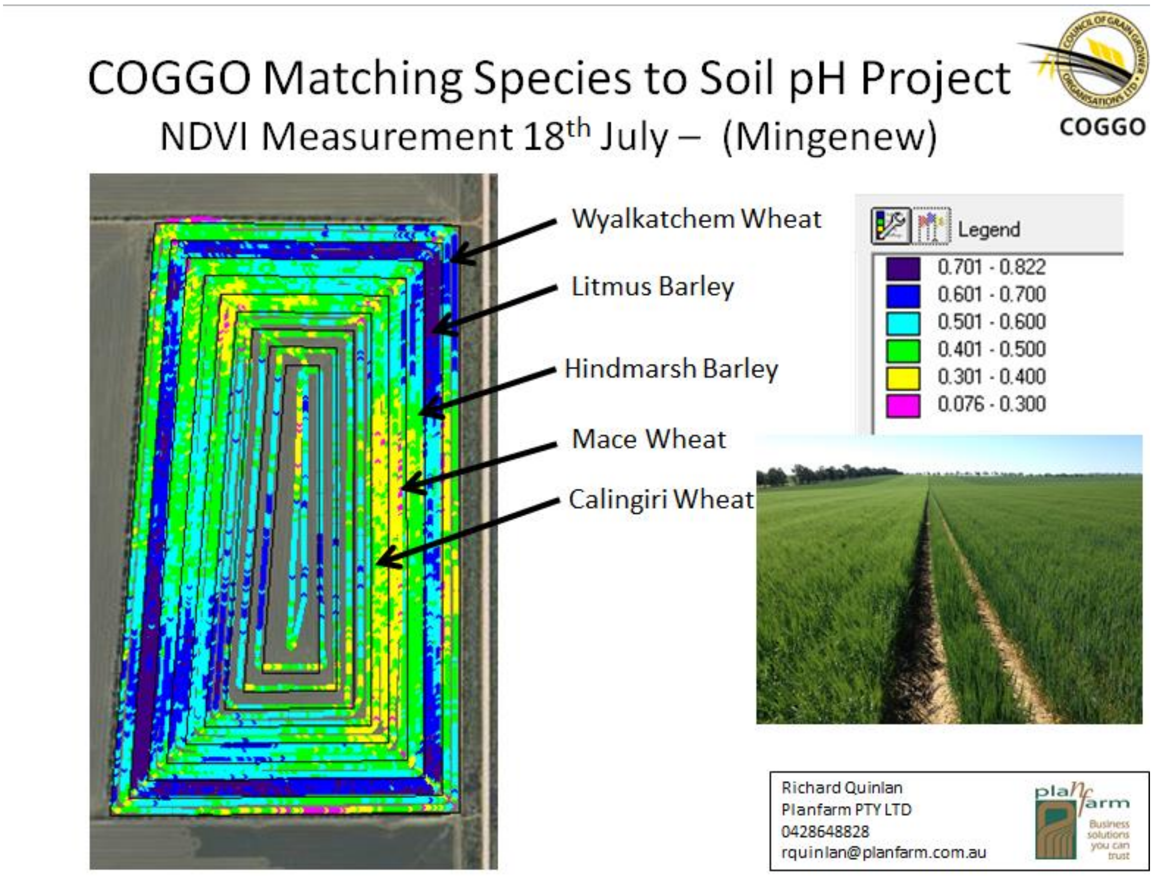
- The natural soil pH of these soils tends to vary between 5.0-5.5 throughout the profile before clearing which is slightly lower than the Yuna site.
- Grain yields tend to be highest in the hollows and lowest on the ridges. Typically the soils are better quality yellow sandy loams in the hollows with better water holding capacity and weaker yellow sands on the ridges with lower water holding capacity. These characteristics have resulted in greater product removal over time leading to sharper declines in soil pH.
- The pH varied markedly across the trial site. There were found to be large pH changes even across relatively small distances (30m) of the grid survey.
- pH is highest in the topsoil due to previous lime applications. These lime applications are yet to move down the profile.
- pH levels decrease with depth with the pH at 20-30cm being the lowest. Compared to the Yuna site pH tends to be lower at depth and deeper down the profile.
- 351 pH samples were taken from 119 sites across the trial paddock to gain insight into how and where the soil pH varied across the trial paddock. Soil pH characteristics at the Mingenew site are contained in (Table 7) below as well as individual pH results in Appendix II.
- Even though the pH (20-30cm) was lowest in the hollows the yield in the hollows was highest due to the better quality soils in these zones.
- Due to the yield data and variation in soil pH on the western side of the trial paddock it was decided to concentrate soil sampling in this region

(Table 7): Mingenew. Soil pH characteristics of the trial site.

	0-10cm	10-20cm	20-30cm
Average Soil pH	5.2	4.6	4.5
pH Range	4.5-6.0	3.9-5.3	3.9-5.2
pH in Hollows (276-281m)	5.1	4.4	4.2
pH on Ridges (282-290m)	5.1	4.6	4.5

NDVI Measurements:

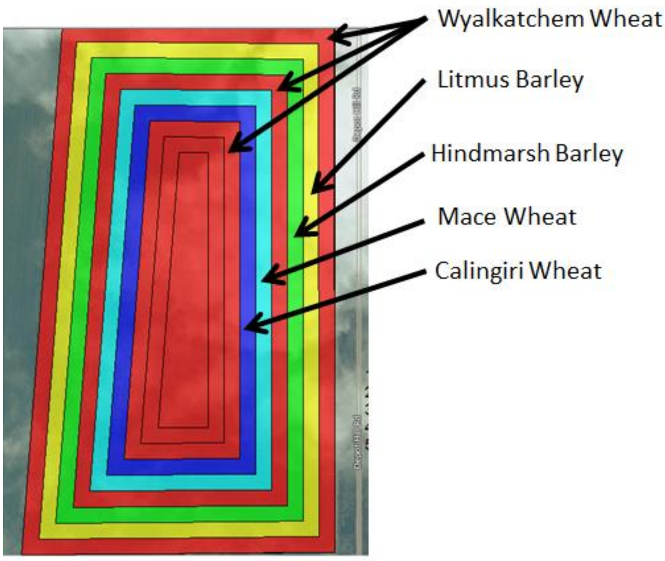
The Mingenew site was measured for relative biomass (NDVI) using the Greenseeker technology (17th July 2014). Figure J shows Litmus barley having a significantly higher NDVI average compared to other treatments.



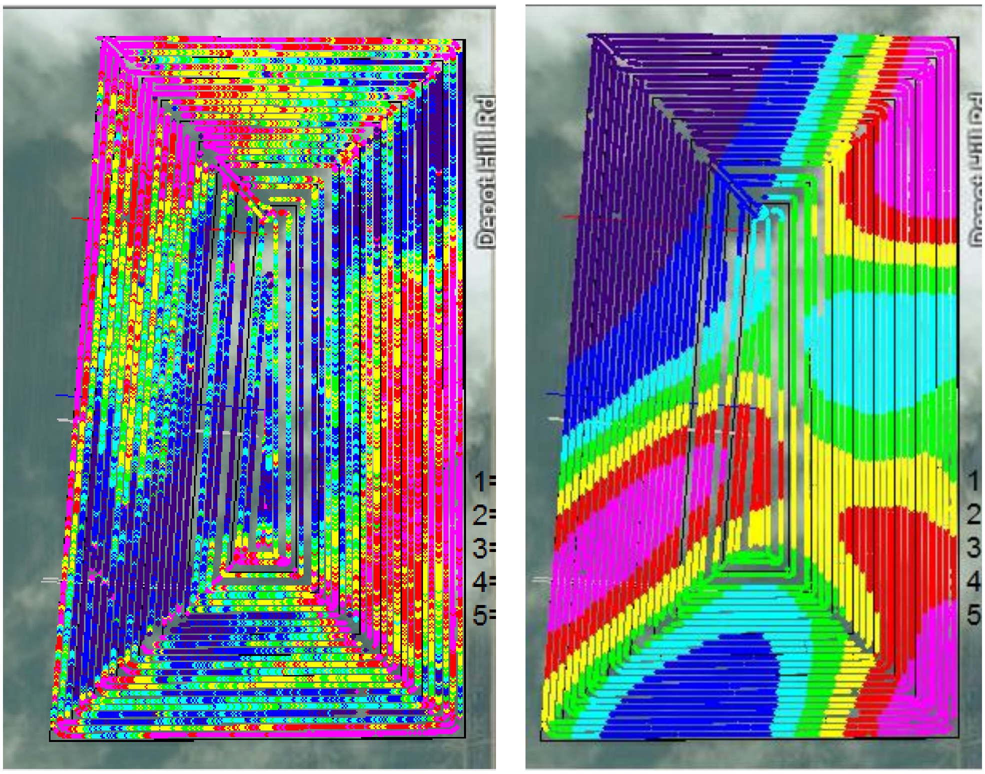
(Figure J): Mingenew: NDVI measurement (17th July 2014)

Yield Results (Mingenew):

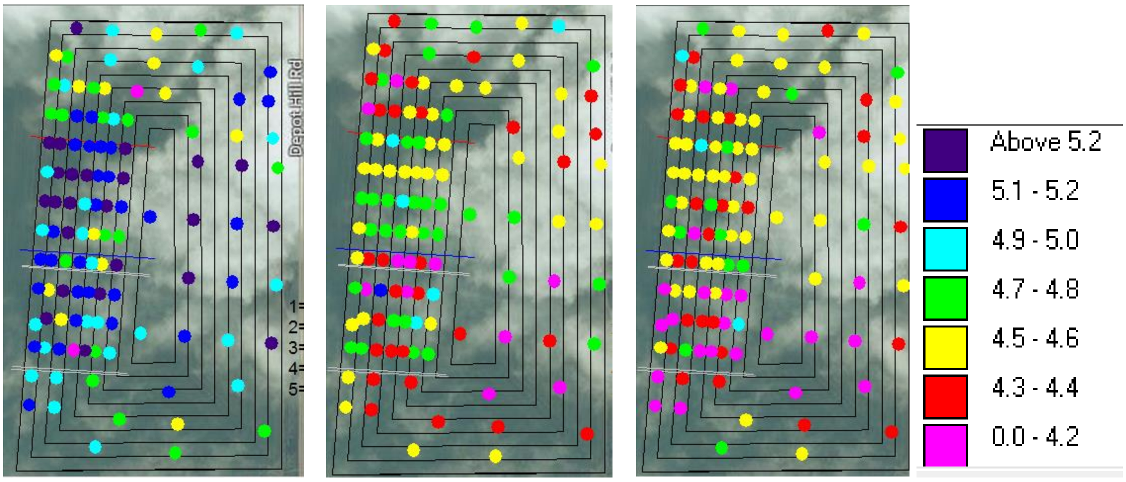
Grain yield was collected from the header harvesting the paddock and is displayed graphically in Figure L.



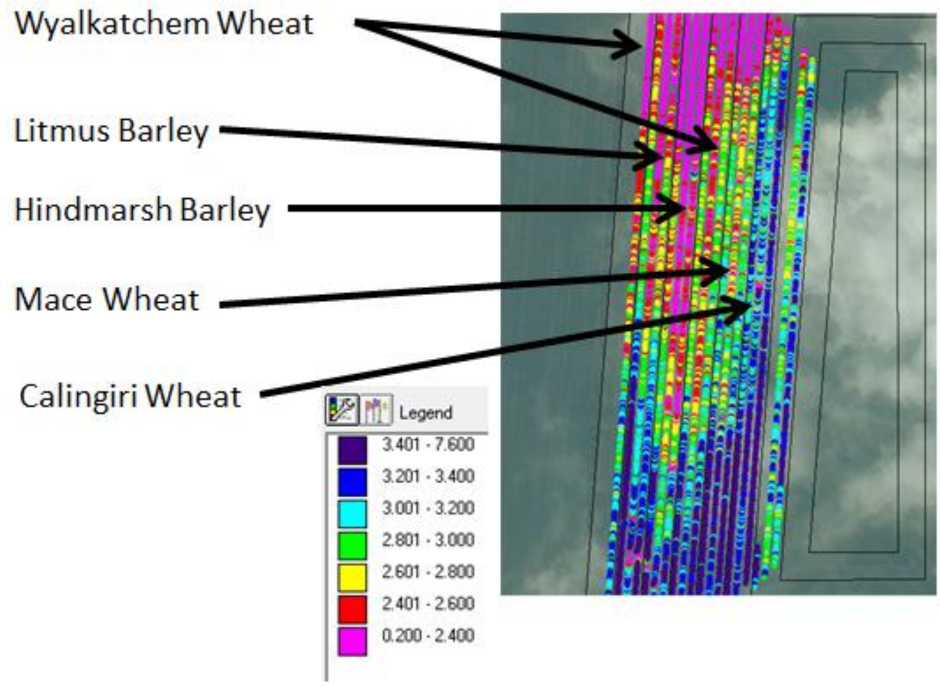
(Figure K) Mingenew: Trial Layout.



(Figure L): Mingenew: Paddock yield (Left): Pink – 2.0 t/ha, Purple – 3.4 t/ha, Elevation (Right), Typical of this region there are stronger yellow sandy loam soils in the hollows and weaker yellow sandy soils on the ridges.



(Figure M): Mingenew: Soil pH (0-10cm) - Left; (10-20cm) – Middle, (20-30cm) – Right. Note the higher pH levels in the 0-10cm depth from previous lime applications. The lime is yet to move down the profile and change the soil pH in the 10-20cm and 20-30cm depths.



(Figure N): Mingenew: Yield data for varieties along the transect (Three header runs per treatment). Note the Wyalkatchem treatment on the western edge was affected by trees on the fenceline, hence only one header run was used for this plot.

Method 1: Varietal analysis along a transect comparing two different soil types:

- Calingiri was the highest yielding variety. It outyielded the next best variety (Litmus) by 140 kg/ha. It is well suited to this soil type. Wyalcatchem was the lowest yielding wheat variety.
- Litmus was the highest yielding barley variety and outyielded Hindmarsh by 390kg/ha (13%).

Due to the range of soil pH levels found on the western region of the paddock, it was decided to split the paddock into 2 transects. This will then allow for variety comparisons as soil types change. The northern transect is typified by weaker yellow sandy loams with higher soil pH levels especially at depth. The Southern zone is typified by stronger yellow sandy loams with lower soil pH levels especially at depth. Yields were also normalised to remove the yield advantages of some varieties. This allowed for comparisons of varieties as soil type changed.

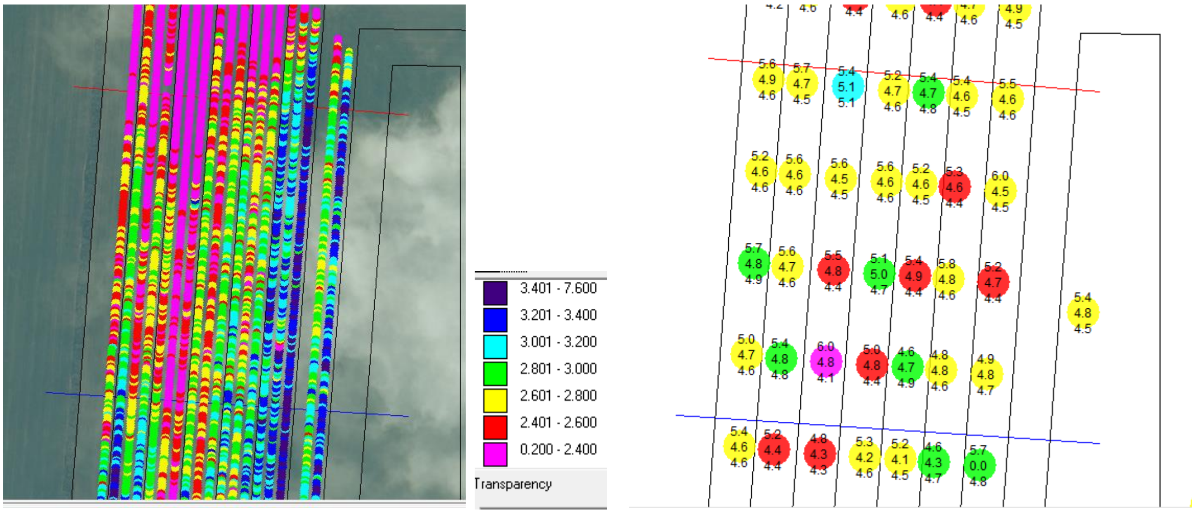
There were not stark changed in how varieties yielded relative to each other between zones. This suggests that Litmus failed to generate marked yield advantages as pH decreased. The comparison is hard to make as various soil characteristics are changing as the pH changes and therefore yield is being driven by a number of factors.

Species/Variety interaction Northern transect (Poorer soils with higher subsoil pH). (Western Side):

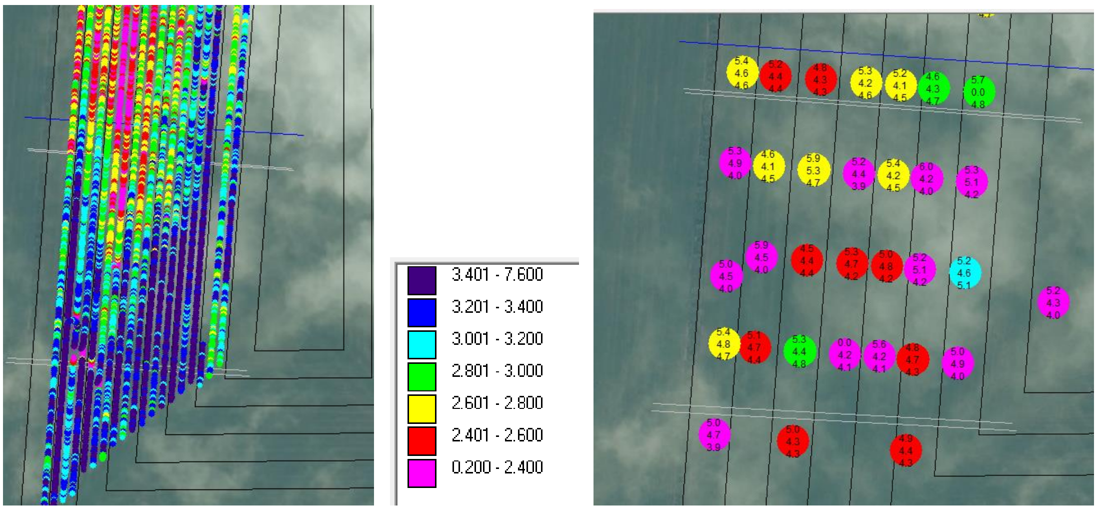
- Calingiri was the highest yielding variety. It proved well suited to these soils and is still widely grown in this district.
- Hindmarsh was the lowest yielding treatment in this transect.
- Litmus outyielded Hindmarsh by 340 kg/ha (12%)
- The average of the pH data within this transect was more uniform than the Yuna site across the treatments.

Variety interaction Southern transect (Stronger soils with lower subsoil pH). (Western Side) (Tables 8 & 9):

- Hindmarsh was the lowest yielding treatment across both soil types selected. This is the opposite of the Yuna trial site where Hindmarsh was the highest yielding variety.
- Litmus outyielded Hindmarsh by 340kg/ha (13%). The northern transect yield difference between Litmus was a similar amount (13%) suggesting there was not a relative advantage of Litmus compared to Hindmarsh on this more acidic soil type. Compared to wheat, Litmus was better on the stronger more acidic soil compared to Wyalkatchem but slightly weaker compared to Calingiri.
- Calingiri was the highest yielding treatment. It outyielded all other varieties across both soil types. It is well suited to these soil types. It performed slightly better relative to Mace on the stronger more acidic soil and relatively the same as Wyalkatchem.
- .Wyalkatchem was the lowest yielding wheat variety on both soil types at Mingenew.



(Figure O): Mingenew: Location of northern transects for yield (t/ha) and soil pH data is presented in (Table 8) below: - (Mingenew)



(Figure P): Mingenew: Location of transects where yield and soil pH data was extracted (ie between two double lines) and presented in (Table 8) below.

(Table 8): Mingenew: Yield and soil pH extracted from yield maps along the western edge of the trial paddock. The northern transect represents poorer soil type with better subsoil pH. The Southern transect represents stronger soil type with intense subsoil pH issues.

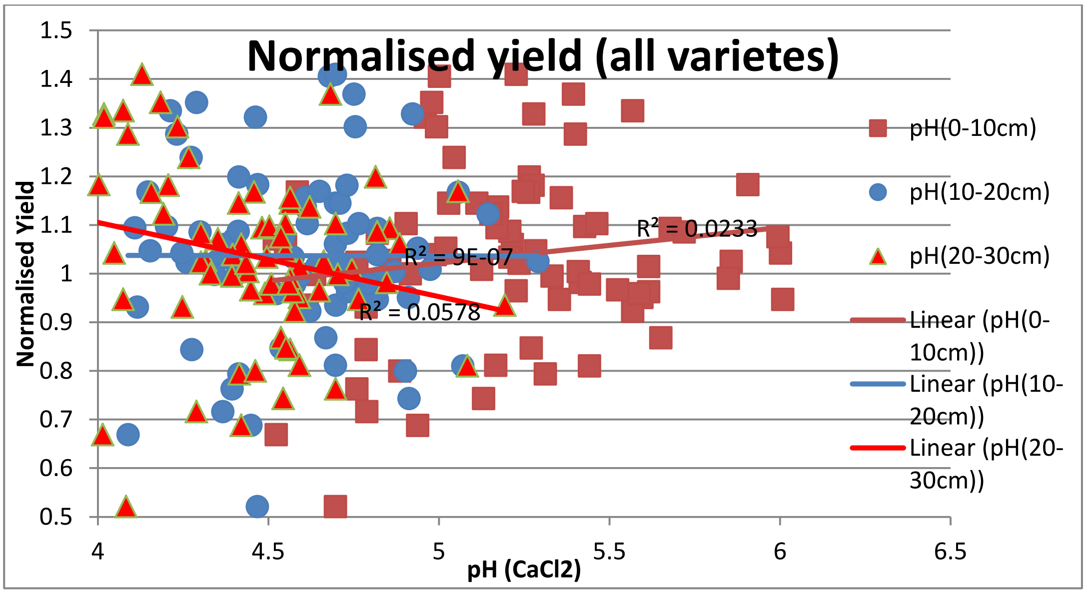
Treatment	Adjusted Yield (t/ha) (Common Plot Design)	Yield (% Wyalkatchem)	Normalised Yield	Normalised Yield (% Wyalkatchem)	Average pH (CaCl) (0-10cm, 10-20cm, 20-30cm)
Full Transect (Western side)					
Wyalkatchem	2.99	100%	1.01	100%	5.1, 4.5, 4.4
Litmus	3.17	106%	1.06	104%	5.4, 4.6, 4.5
Hindmarsh	2.78	93%	1.01	100%	5.4, 4.7, 4.5
Mace	3.09	103%	1.03	101%	5.2, 4.5, 4.5
Calingiri	3.31	111%	1.03	102%	5.2, 4.6, 4.4
Northern Transect (Poorer soil type with higher subsoil pH)					
Wyalkatchem	2.81	100%	0.95	100%	5.3, 4.8, 4.6
Litmus	2.88	103%	0.96	101%	5.5, 4.8, 4.6
Hindmarsh	2.54	91%	0.94	98%	5.6, 4.8, 4.5
Mace	2.80	100%	0.98	103%	5.1, 4.7, 4.7
Calingiri	3.10	111%	0.94	99%	5.4, 4.7, 4.5
Southern Transect (Stronger Soil type with lower subsoil pH)					
Wyalkatchem	3.19	100%	1.09	100%	5.2, 4.7, 4.3
Litmus	3.41	107%	1.14	105%	5.2, 4.4, 4.3
Hindmarsh	3.00	94%	1.12	103%	5.2, 4.6, 4.5
Mace	3.38	106%	1.13	104%	5.3, 4.4, 4.3
Calingiri	3.55	111%	1.06	97%	5.2, 4.6, 4.2

(Table 9): Mingenew: Relative Yields of Varieties for the 2 selected soil types.

	Adjusted Yield (t/ha)	Average pH (CaCl) (0-10cm, 10-20cm, 20-30cm)	cf Wyal	cf Mace	cf Calingiri	cf Litmus	cf Hindmarsh
Northern Transect (Poorer soil type with higher subsoil pH)							
Wyalkatchem	2.99	5.1, 4.5, 4.4	100%	97%	90%	94%	108%
Litmus	3.17	5.4, 4.6, 4.5	106%	103%	96%	100%	114%
Hindmarsh	2.78	5.4, 4.7, 4.5	93%	90%	84%	88%	100%
Mace	3.09	5.2, 4.5, 4.5	103%	100%	93%	97%	111%
Calingiri	3.31	5.2, 4.6, 4.4	111%	107%	100%	104%	119%
Southern Transect (Stronger Soil type with lower subsoil pH)							
Wyalkatchem	2.81	5.3, 4.8, 4.6	100%	100%	90%	97%	110%
Litmus	2.88	5.5, 4.8, 4.6	103%	103%	93%	100%	113%
Hindmarsh	2.54	5.6, 4.8, 4.5	91%	91%	82%	88%	100%
Mace	2.80	5.1, 4.7, 4.7	100%	100%	90%	97%	110%
Calingiri	3.10	5.4, 4.7, 4.5	111%	111%	100%	108%	122%

Method 2: Varietal analysis around each soil test site:

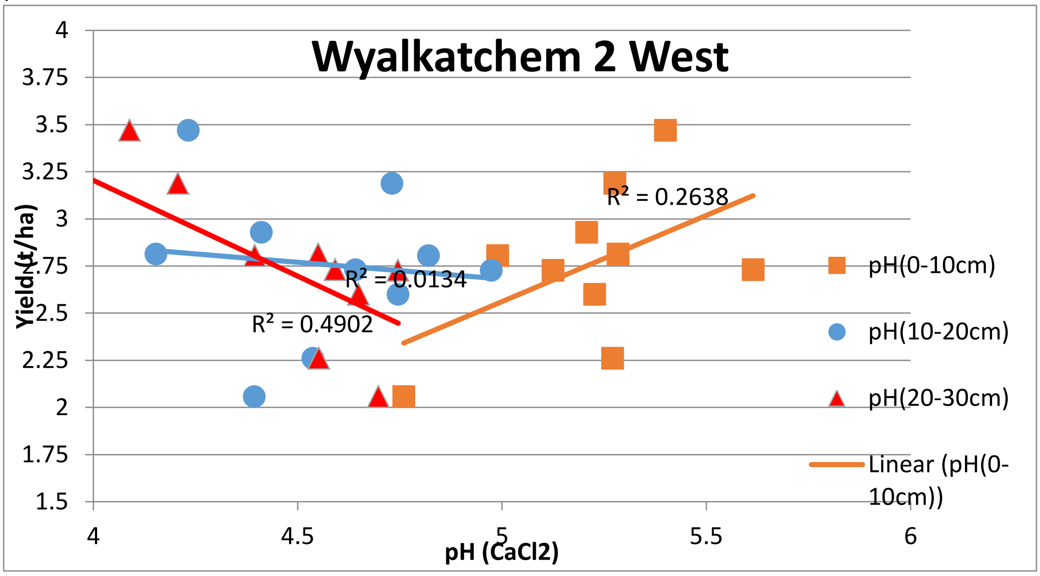
Around each soil pH test site (40m diameter) the yield data was averaged and presented below. The yield data for each species/variety was normalised according to each varieties plot average on the western side of the paddock. See raw data in (Appendix II).



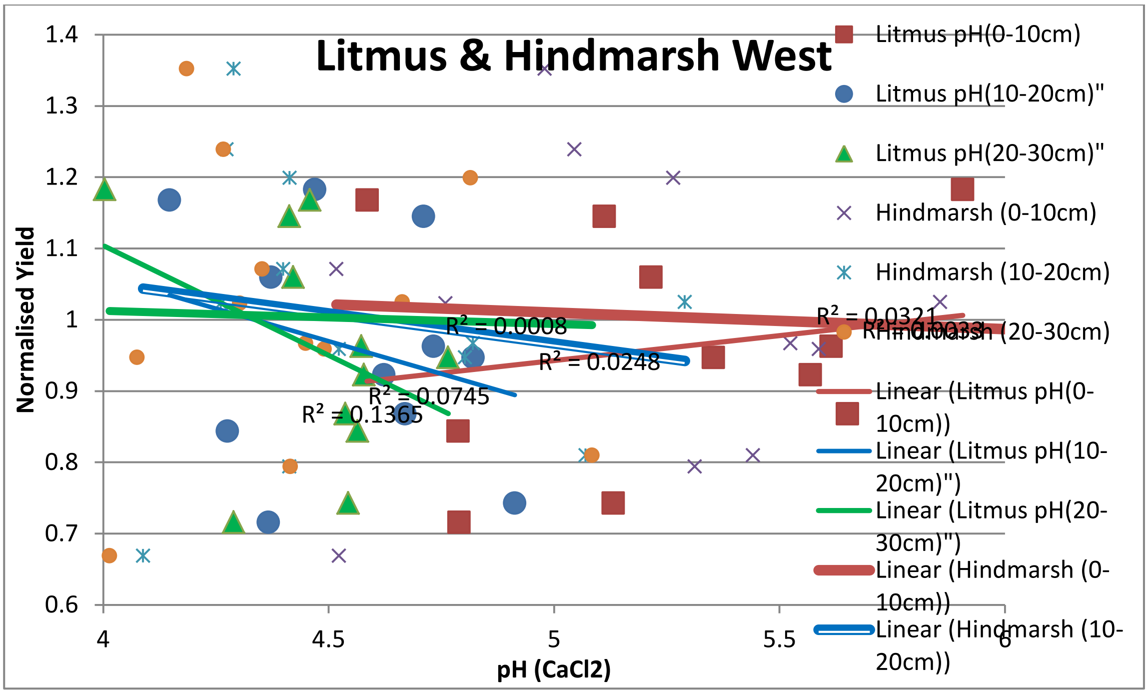
(Figure Q): Normalised yields in a 40m diameter around each soil pH test site on the western site of the Mingenew paddock. Yields were normalised to the average yield for each species/variety on the western side of the paddock. Overall there was no correlation between soil pH and yield.

There was a poor correlation between soil pH and yield for the various varieties (Figure Q). The best correlation between soil pH and yield occurred with Wyalkatchem (Figure R). Note the following observations from the data:

- The best correlation (R^2=0.49) between yield and pH occurred at the 20-30cm depth. This was a negative correlation. Ie a lower pH measured at this depth resulted in increasing yield. This was the opposite of the Yuna site suggesting a different process is in play on these soils. This is likely to be the result of better soils giving increased yield even though they are more acidic. The lower pH of these soils is likely to be the result of greater historical grain removal.
- Higher yields occurred on the better soil types where over the years the increased production (product removal) has resulted in the generation of more acidity and therefore a more acid soil profile.



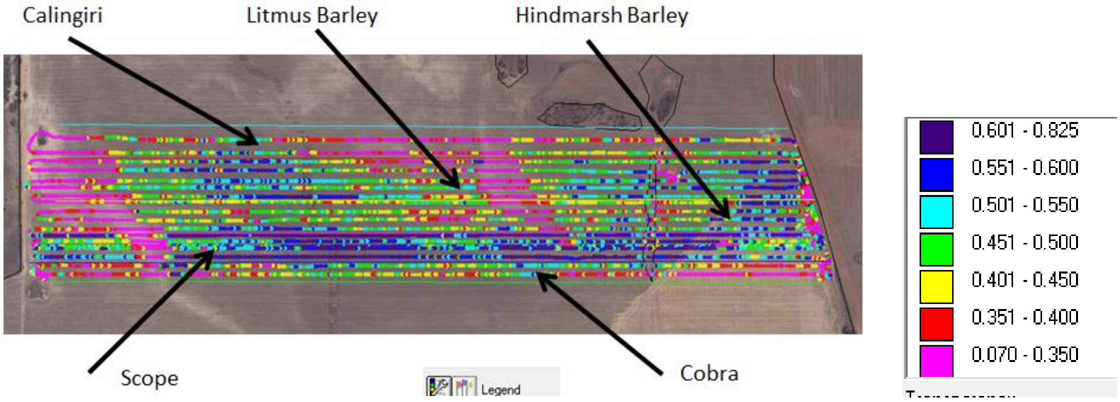
(Figure R): The correlation between Wyalkatchem yield and soil pH. The strongest correlation between yield and pH was at the 20-30cm depth. At this depth the correlation was negative (ie as pH increased the yield decreased). The effect is occurring due to changes in soil type. Ie where soil type is improving and product removal has been higher over the years then pH has dropped further.



(Figure S): Mingenew: Litmus does not appear to tolerate lower pH soils better than Hindmarsh. Or the yield of Litmus and Hindmarsh is not being driven by soil pH at any depth. Rather it is probably being driven by better soils types where the soil pH is low.

THREE SPRINGS SITE:

The three Springs site was measured for relative NDVI. The variety Scope showed higher green leaf index than other sites as this stage.



(Figure T) Three Springs: NDVI survey of the trial site 17 July 2014

Yield Results:

The Three Springs site contained high levels of rhizoctonia root rot which was randomly spread throughout the trial site. This disease caused the yield maps to be highly variable which confounded the interactions between pH and variety. For this reason it was decided to not pH sample the site and conduct comparisons with yield. This allowed for a more intensive sampling regime for the other 2 sites in the project.

Conclusions & Recommendations:

Varieties performed very differently depending on the trial site. Calingiri was well suited to the soils where the Mingenew trial site were located but performed the worst at the Yuna site. Hindmarsh however was better suited to the Yuna site where it was the highest yielding variety but performed the worst out of all varieties at the Mingenew site.

More importantly for this project we were looking at the relative yields between the varieties both within the site and between the sites to determine whether soil acidity was playing a major role in variety performance. To do this there were 2 methods of comparison performed. Method 1 selected 2 soil types within the trial area and compared relative yields of the varieties to the average pH found along the transect. Method 2 collected yield data in the 40m diameter around each pH sampling point for each variety and correlated yield and soil pH

The Method 1 analysis showed Litmus performing relatively better at both sites where the pH was low. It increased its relative yield compared to all varieties at the low pH site in Mingenew and increased its relative yield compared to all varieties except Hindmarsh at the low pH site at Yuna. Its total yield however fell short of the best performing varieties at both sites. This suggests if Litmus pH tolerance could be inserted into a better yielding variety there could be tangible benefits. Calingiri was the highest yielding variety at the Mingenew low pH site but performed the worst at the Yuna low pH site.

The soil profile study carried out at Yuna under Litmus and Hindmarsh shows clearly that Litmus was able to extract more moisture out of the profile than Hindmarsh. Although it didn't yield better than Hindmarsh it showed the root system was achieving significant benefits on acidic soils.

Method 2 showed the correlation between soil pH and yield was poor suggesting yield was not driven by pH alone. The best of these yield vs soil pH correlations occurred when the pH measured at 20-30cm depth was correlated with yield.

The grid survey also showed large variations in soil pH occurred across relatively small distances spatially. This was especially the case at the Yuna site.

At the Mingenew site the correlation between yield and soil pH was poor but negative. Ie as pH decreased the yield increased, which suggested other factors were responsible for the correlation. These are likely to be that the best soils have the lowest pH at depth due to product removal over time reducing the pH of these productive soils. Despite the pH being low they are still performing better than the weaker soils. At the Yuna site the correlation was poor but positive and better represents the pH effect on yield.

To remove the confounding issue of moisture holding capacity and nutrition the project should have located trial sites where pH had previously been addressed however it is unlikely that such sites are present in the NAR of Western Australia. Spading or mouldboarding of lime into the profile are likely to cause other issues that confound this method of analysis.

(Appendix I): Yuna: Raw and normalised yield data in a 40m radius around each soil pH site.

Site	Latitude	Longitude	Variety		Yield Normalised Yield		pH(0-10cm)	pH(10-20cm)	pH(20-30cm)
1	-28.4348	115.0103	Scope		2.01	0.809	5.1	5.0	5.6
2	-28.4363	115.0104	Scope		2.423	0.976	5.0	4.8	4.9
3	-28.4383	115.0104	Scope		2.613	1.053	5.1	5.8	4.6
4	-28.4409	115.0104	Scope		1.871	0.754	4.9	4.6	4.8
5	-28.4435	115.0104	Scope		2.971	1.196	4.9	5.1	4.8
6	-28.446	115.0105	Scope		2.962	1.193	4.8	4.4	4.6
8	-28.449	115.0101	Hindmarsh		2.839	0.991	4.8	5.6	5.6
9	-28.4447	115.0101	Hindmarsh		3.282	1.003	4.9	4.9	4.9
10	-28.4422	115.0101	Hindmarsh		2.917	1.006	5.7	5.0	4.9
11	-28.4396	115.01	Hindmarsh		2.753	1.004	5.0	4.8	4.7
12	-28.437	115.01	Hindmarsh		3.057	0.998	4.3	4.6	4.9
13	-28.4383	115.0097	Litmus		2.857	1.05	5.2	4.6	4.9
14	-28.4409	115.0097	Litmus		1.872	0.688	5.0	5.6	5.1
15	-28.4435	115.0097	Litmus		2.829	1.04	5.0	4.9	4.8
16	-28.449	115.0094	Scope		2.67	1.077	4.8	5.1	5.2
17	-28.4461	115.0094	Scope		2.85	1.148	5.0	4.7	5.0
18	-28.4422	115.0093	Scope		2.791	1.124	4.9	5.0	4.6
19	-28.4396	115.0093	Scope		2.791	1.126	5.0	4.9	5.0
20	-28.437	115.0093	Scope		1.906	0.768	5.3	4.8	3.9
21	-28.4363	115.0089	Calingiri		0.789	0.431	6.0	4.3	3.5
22	-28.4348	115.0092	Scope		2.5	1.007	4.7	3.7	4.2
23	-28.4383	115.0089	Calingiri		1.857	1.014	5.7	4.5	4.9
24	-28.4409	115.0089	Calingiri		1.487	0.812	5.8	4.8	5.2
25	-28.4435	115.009	Calingiri		1.4	0.764	4.7	4.6	4.2
26	-28.448	115.0086	Mace		2.181	0.992	4.8	4.7	4.9
27	-28.4448	115.0086	Mace		1.935	0.881	5.5	5.0	4.6
28	-28.4422	115.0086	Mace		2.716	1.236	4.4	5.0	4.3
29	-28.4396	115.0086	Mace		2.881	1.311	4.7	4.4	4.9
30	-28.437	115.0085	Mace		1.301	0.592	5.0	4.3	4.7
31	-28.4383	115.0082	Scope		2.736	1.102	4.5	3.6	4.7
32	-28.4409	115.0082	Scope		3.038	1.223	5.2	4.4	4.7
33	-28.4435	115.0082	Scope		2.982	1.201	4.6	4.1	4.2
34	-28.449	115.0079	Litmus		2.174	0.298	4.9	4.5	4.4
35	-28.4461	115.0079	Litmus		3.042	1.118	5.4	4.4	4.5
36	-28.4422	115.0079	Litmus		3.229	1.187	5.2	4.1	4.5
37	-28.4396	115.0078	Litmus		3.187	1.171	4.9	5.4	5.5

38	-28.437	115.0078	Litmus		2.522	0.927	4.9	4.6	4.6
39	-28.4348	115.0077	Litmus		2.904	1.067	5.5	4.6	5.9
40	-28.4383	115.0074	Hindmarsh		2.588	1.015	4.6	3.9	4.4
41	-28.4409	115.0075	Hindmarsh		3.031	0.999	5.8	4.8	5.4
42	-28.4435	115.0075	Hindmarsh		3.456	0.998	5.2	5.0	4.4
43	-28.448	115.0071	Hindmarsh		2.179	0.877	4.9	4.2	4.8
44	-28.4448	115.0071	Scope		3.091	1.245	4.9	4.4	4.7
45	-28.4422	115.0071	Scope		2.973	1.197	4.7	5.2	4.4
46	-28.4396	115.0071	Scope		2.244	0.904	5.7	3.7	4.2
47	-28.437	115.0071	Scope		1.738	0.7	4.8	3.9	3.8
48	-28.4364	115.0074	Hindmarsh		2.495	1.004	5.4	4.4	4.7
49	-28.4383	115.0067	Calingiri		1.629	0.889	4.8	4.9	4.2
50	-28.4409	115.0067	Calingiri		0.804	0.439	5.4	4.5	4.5
51	-28.4435	115.0068	Calingiri		2.868	1.565	4.8	5.0	5.4
52	-28.4491	115.0064	Mace		2.325	1.06	5.4	3.6	5.1
53	-28.4461	115.0064	Mace		3.072	1.398	4.8	4.3	5.1
54	-28.4422	115.0064	Mace		2.989	1.36	5.0	5.3	5.4
55	-28.4396	115.0064	Mace		2.058	0.937	4.6	4.0	4.0
56	-28.437	115.0063	Mace		1.603	0.729	5.2	4.6	4.6
57	-28.4364	115.0063	Mace		1.416	0.644	4.9	4.5	4.4
58	-28.4349	115.0063	Mace		1.509	0.687	5.1	5.0	4.5

(Appendix II): Mingenew. Raw and normalised yield data in a 40m radius around each soil pH site on the western edge of the Mingenew paddock.

Site	Latitude	Longitude	Treat	Yield (t/ha)	Normalised Yield	pH(0-10cm)	pH(10-20cm)	pH(20-30cm)
6	-28.9629	115.33328	W1	2.2	0.94	4.6	4.7	5.2
12	-28.9637	115.33322	W1	2.4	1.03	4.9	4.4	4.3
21	-28.9644	115.33316	W1	2.2	0.93	4.8	4.1	4.2
31	-28.9651	115.33309	W1	2.2	0.95	5.6	4.9	4.6
41	-28.9658	115.33303	W1	2.7	1.14	5.2	4.6	4.6
48	-28.9665	115.33297	W1	2.5	1.09	5.7	4.8	4.9
59	-28.9672	115.3329	W1	2.7	1.15	5.0	4.7	4.6
66	-28.968	115.33284	W1	2.7	1.16	5.4	4.6	4.6
76	-28.9687	115.33278	W1	3.1	1.33	5.3	4.9	4.0
93	-28.9696	115.3327	W1	3.1	1.32	5.0	4.5	4.0
94	-28.9701	115.33267	W1	3.2	1.37	5.4	4.8	4.7
102	-28.9708	115.33258	W1	3.3	1.41	5.0	4.7	3.9
111	-28.9715	115.33252	W1	3.3	1.41	5.2	4.7	4.1
7	-28.963	115.33359	L	2.1	0.72	4.8	4.4	4.3
13	-28.9637	115.33352	L	2.1	0.74	5.1	4.9	4.5
22	-28.9644	115.33346	L	2.4	0.84	4.8	4.3	4.6
32	-28.9651	115.3334	L	2.5	0.87	5.7	4.7	4.5
42	-28.9658	115.33333	L	2.7	0.92	5.6	4.6	4.6
49	-28.9665	115.33327	L	2.8	0.96	5.6	4.7	4.6
60	-28.9673	115.33321	L	2.7	0.95	5.4	4.8	4.8
67	-28.968	115.33314	L	3.0	1.06	5.2	4.4	4.4
77	-28.9687	115.33308	L	3.4	1.17	4.6	4.1	4.5
83	-28.9694	115.33301	L	3.4	1.18	5.9	4.5	4.0
95	-28.9701	115.33295	L	3.3	1.15	5.1	4.7	4.4
14	-28.9637	115.33393	H	1.7	0.67	4.5	4.1	4.0
23	-28.9644	115.33387	H	2.1	0.79	5.3	4.4	4.4
33	-28.9651	115.33381	H	2.1	0.81	5.4	5.1	5.1
43	-28.9659	115.33374	H	2.5	0.96	5.6	4.5	4.5
50	-28.9666	115.33368	H	2.5	0.97	5.5	4.8	4.4
61	-28.9673	115.33362	H	2.5	0.95	6.0	4.8	4.1
68	-28.968	115.33355	H	2.7	1.02	4.8	4.3	4.3
78	-28.9687	115.33349	H	2.7	1.03	5.9	5.3	4.7
84	-28.9694	115.33342	H	2.8	1.07	4.5	4.4	4.4
96	-28.9702	115.33336	H	3.1	1.20	5.3	4.4	4.8

104	-28.9709	115.3333	H	3.2	1.24	5.0	4.3	4.3
112	-28.9716	115.33323	H	3.5	1.35	5.0	4.3	4.2
15	-28.9637	115.33434	W2	2.1	0.76	4.8	4.4	4.7
24	-28.9645	115.33428	W2	2.3	0.85	5.3	4.5	4.6
34	-28.9652	115.33422	W2	2.6	0.97	5.2	4.7	4.6
44	-28.9659	115.33415	W2	2.7	1.02	5.6	4.6	4.6
51	-28.9666	115.33409	W2	2.7	1.01	5.1	5.0	4.7
62	-28.9673	115.33403	W2	2.8	1.04	5.0	4.8	4.4
69	-28.968	115.33396	W2	2.8	1.05	5.3	4.2	4.6
79	-28.9688	115.3339	W2	2.9	1.09	5.2	4.4	3.9
85	-28.9695	115.33383	W2	3.2	1.18	5.3	4.7	4.2
97	-28.9702	115.33377	W2	3.5	1.29	5.4	4.2	4.1
16	-28.9638	115.33466	M	1.4	0.52	4.7	4.5	4.1
25	-28.9645	115.33459	M	1.9	0.69	4.9	4.4	4.4
35	-28.9652	115.33453	M	2.7	0.98	5.4	4.7	4.8
45	-28.9659	115.33447	M	2.8	1.03	5.2	4.6	4.5
52	-28.9666	115.3344	M	2.8	1.00	5.4	4.9	4.4
63	-28.9673	115.33434	M	2.9	1.06	4.6	4.7	4.9
70	-28.9681	115.33428	M	3.0	1.09	5.2	4.1	4.5
80	-28.9688	115.33421	M	3.0	1.10	5.4	4.2	4.5
86	-28.9695	115.33415	M	3.6	1.30	5.0	4.8	4.2
98	-28.9702	115.33409	M	3.7	1.34	5.6	4.2	4.1
26	-28.9645	115.33489	C	2.7	0.81	5.2	4.7	4.6
36	-28.9652	115.33483	C	3.3	0.98	5.4	4.6	4.5
46	-28.9659	115.33477	C	3.3	0.99	5.3	4.6	4.4
53	-28.9666	115.3347	C	3.3	0.99	5.8	4.8	4.6
64	-28.9674	115.33464	C	3.3	0.98	4.8	4.8	4.6
71	-28.9681	115.33458	C	3.3	1.00	4.6	4.3	4.7
81	-28.9688	115.33451	C	3.5	1.04	6.0	4.2	4.0
87	-28.9695	115.33445	C	3.7	1.12	5.2	5.1	4.2
99	-28.9702	115.33439	C	3.6	1.08	4.8	4.7	4.3
106	-28.9709	115.33432	C	3.3	1.00	4.9	4.4	4.3
27	-28.9645	115.3353	W3	2.3	0.80	4.9	4.9	4.5
37	-28.9652	115.33524	W3	3.2	1.10	5.5	4.6	4.6
47	-28.966	115.33518	W3	3.1	1.08	6.0	4.5	4.5
54	-28.9667	115.33511	W3	2.9	1.02	5.2	4.7	4.4
65	-28.9674	115.33505	W3	3.2	1.10	4.9	4.8	4.7
72	-28.9681	115.33499	W3	3.1	1.09	5.7	4.3	4.8

82	-28.9688	115.33492	W3	3.3	1.17	5.3	5.1	4.2
88	-28.9695	115.33486	W3	3.4	1.17	5.2	4.6	5.1
100	-28.9703	115.3348	W3	3.0	1.05	5.0	4.9	4.0

3. Project resources	This section describes use of the funding listed in the initial plan and any refunds due to COGGO

Expenditure of funds requested from COGGO	$ Total funds budgeted	$ Total funds expended (actual)	$ Total funds requested from COGGO*	$ Total COGGO funds expended	$ Refund due to COGGO of any unexpended COGGO funds
Salary/Contractors	40,000	40,000	40,000	40,000	0
Operating costs	10,000	10,000	10,000	10,000	0
Capital	0	0	0	0	0
TOTAL	**50,000**	**50,000**	**50,000**	**50,000**	**0**

*Funding provided by COGGO.

IMPORTANT: Return of unused funds to COGGO is required as per *Clause 3.3* of the Research Agreement.

4. Commercialisation	Insert details of the proposed commercialisation process,as applicable, with reference back to the planned commercialisation plan in the project proposal) for any outputs from the project. This should include recommendations for the commercialisation of the results of the project and the registration or other protection of Project IP and Project Confidential Information as per the Research Agreement.

None

It is understood that this may require further discussion and agreement with COGGO via its' agent GIWA, as per the undertakings given and terms agreed, in the project proposal. This can be the subject of an appended letter and attachments. In all cases such discussion and subsequent agreements need to be governed by *Section 8 Project IP, Improvements and Project Confidential information* of the Research Agreement.

5. Communication/	Insert details of how the communication and extension of the project outcomes has been achieved to date and recommendations for future activities to disseminate and promote

Extension	adoption of the results of the Project.
Field walks as part of the Yuna field day were held in 2014. The results will now be disseminated to Barley plant breeders and can be spread through Update meetings and various agricultural newsfeeds.	

Note: As per *Clause 7.3 (b) (ii)* of the Research Agreement COGGO may require the Researcher to produce an edition of the Final Report in a form suitable for general distribution. If so required by COGGO, the Researcher must produce a non-confidential version of the Final Report within 28 days of receiving a request to that effect from COGGO.

6. Certification

The Project Supervisor and the Research Organisation certify that all information contained in, and forming part of, this final project report is complete and accurate. The project supervisor and research organisation further warrant that the project complied with all the relevant guidelines affecting the conduct of research, for example in relation to ethics, bio-safety, environmental legislation, GMAC or National Health and Medical Research Council Codes.

Project Supervisor's signature ______________________________

Name (in Capitals)

______________________________ Date:

Research Organisation signature ______________________________

Name and title of authorised signatory (in Capitals)

____

______________________________Date:

Completed Final Project reports

Email to coggoresearchfund@giwa.org.au or mail to
COGGO Research Fund, GIWA, PO Box 1081, Bentley DC, WA 6983

For any further enquiries please email questions to coggoresearchfund@giwa.org.au

Or phone (08) 6262 2128

COGGO representative

For the purpose of this Project agreement contract, COGGO will be represented by Grains Industry Association of Western Australia (GIWA), or such other representative that is nominated by COGGO as authorised to operate on behalf of COGGO.