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How much yield will you leave in the field this harvest?

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The term 'yield gap' refers to the difference between the actual yield and the potential yield that can be achieved across a farm or field. Across the world, the yield for wheat crops varies from approximately 2t/ha to 8.7t/ha.

Australia has the lowest average yield across the country whereas Europe has the highest. Table 1 shows the data from the GRDC on the yield and yield gap across eastern Australia. The table shows that Australian farms are producing around 50 percent of the wheat that is the potential to produce.

Water is a limiting factor in many regions of Australia. Farmers have no ability to affect the rainfall, whereas they can take action where their fields are nutrient limited. Nitrogen, phosphorus and potassium are the key nutrients that can drive yield. However,nitrogen is the major nutrient that directly increases yield if applied correctly.

Brill et al, 2012, have shown that variable rate fertilization of nitrogen can produce a positive yield response in zones where the protein content of the grain is less than 11.5 percent. Figure 1 shows the effect of applying 0, 30, 60, 90 and 120kg/ha of Nitrogen in Australia wheat variety trials.

Note that at 120kg/ha nitrogen fertilisation rate, the yield reaches an optimum of 4.1t/ha and the protein content was 11.2 percent. In contrast, at lower rates of nitrogen application, the yield is lower, and the protein content is also lower. The CropScan 3300H On Combine NIR Analyser measures protein in real time as the grain is stripped in the field.

Measuring protein and yield of the grain across the field allows a new field map to be generated, ie, protein/yield correlation quadrant map (See figure 2). This map shows four performance zones which can show farmers where they can produce a positive yield and protein response by selectively applying more nitrogen fertiliser into the zones that are nitrogen limited.

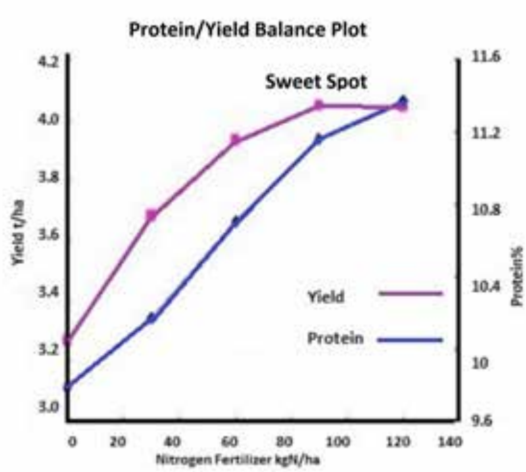


Figure 1- Grain yield (t/ha) and protein concentration (%) from 10 wheat varieties with 0, 30, 60, 90 and 120 kg/ha applied nitrogen in a trial at Parkes in 2011 (Brill et al)

How much nitrogen to apply?

A farmer, Matt Hill, Esperance, WA, conducted strip trials to see how much yield increased with the application of higher rates of 'Flexi N' nitrogen fertiliser. He applied 50, 100, 120 and 200 l/ha rates in the red zones of the adjacent field. The red zone had previously produced low yield and low protein wheat, and thereby was projected to produce a positive yield response to increased nitrogen fertiliser.

Table 2 shows the yield and protein response to increases in the rate of nitrogen applied across the field. Figure 3 is the plot of the yield vs nitrogen rate, which shows that approximately 100 litres of Flexi N fertiliser produces an additional 0.6t/ha and approximately one percent higher protein.

Mr Hill realised that he could have increased this and heightened the nitrogen rate even further. With the cost of the Flexi N at US $.69/l, then the return on investment can be shown in Table 2.

How many dollars are left in the field?

Based on the data collected by Mr Hill, the following chart provides a means of estimating the cost of under fertilising and what additional income could have been achieved by using a CropScan 3300H On Combine Analyser to define the performance zones based on protein and yield.

Discussion:

Variable rate nitrogen fertilisation has been an option for farmers for 20 years, yet so few farmers are actually using VRF to increase their incomes. It has been suggested that VRF is too hard to implement or that applying more nitrogen does not always produce positive yield responses. However, the yield gap is a reality in Australian grain farming and a solution for closing the yield gap offers the industry the greatest step forward to sustainability.

The CropScan 3300H provides the one piece of information that can resolve the two issues that have limited VRF implementation, i.e., a method of measuring nitrogen availability and uptake across the fields. Protein is directly related to nitrogen by a factor of 0.175.

For every kilogram of protein in a tonne of grain, 175 grams of nitrogen is stripped from the soil. By combining protein and yield data off the combine, protein/yield correlation quadrant maps can be generated that clearly shows how much and where nitrogen was stripped from the soil.

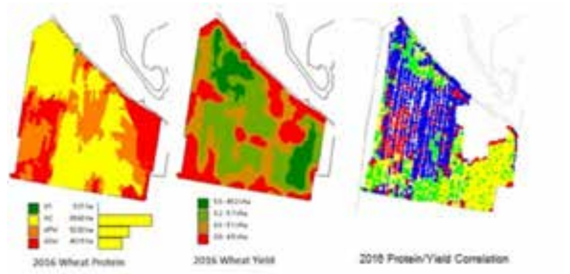
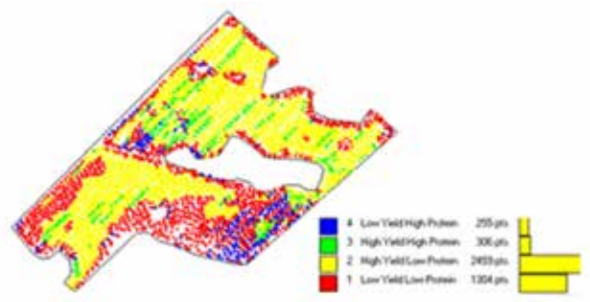


Figure 2- Protein, yield and protein/yield correlation maps for a wheat field in Young, NSW, 2016

Figure 2.2- Protein/yield correlation maps, wheat field, Esperance, WA



Approximately 30 percent of all grain fields across Australia under perform in terms yield and protein. By identifying those

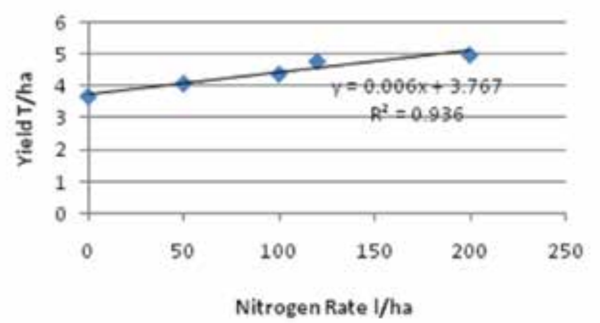


Figure 3. Yield Vs Nitrogen Application Rate

Table 1: Yield gap results for the GRDC regions- 15-year (1666-2010) area weighted values

Region	Ya (kg/ha)	Yw (kg/ha)	Yg (kg/ha)	Y(%)	SLAs
Northern	1668	3580	1912	46.6	48
Southern	1827	3519	1692	51.9	117
Western	1651	2977	1326	55.5	63
National	1806	3477	1671	51.9	259*

*of the 259 SLAs used in the national analysis, 31 fall outside GRDC regions

Table 2: Yellow represents actual field data, green represents extrapolated data

Protein (%)	Applied Flexi N (l/ha)	Yield (t/ha)	Flexi N Cost ($)	Payment ($/ha)	Additional profit ($/ha)
8.3	0	3.7	0	1184	0
8.7	50	4.1	34.5	1312	94
9.1	100	4.4	69	1408	155
9.6	120	4.8	82.8	1536	269
10.1	200	5	138	1600	278
10.6	250	5.3	172.5	1696	340
11.1	300	5.6	207	1792	401
11.6	350	5.8	241.5	1856	431

Table 3. The cost of lost yield as a result of under fertilisation

Dollars (US$) left in the field per ha

Protein (%)	3.5t/ha	4.0t/ha	4.5t/ha	5t/ha	5.5t/ha	6t/ha	6.5t/ha
8.5	-$330	-$275	-$220	-$165	-$110	-$55	$0
9	-$275	-$220	-$165	-$110	-$55	$0	$0
9.5	-$220	$165	-$110	-$55	$0	$0	$0
10	-$195	-$130	-$65	$0	$0	$0	$0
10.5	-$130	-$55	$0	$0	$0	$0	$0
11	-$65	$0	$0	$0	$0	$0	$0
11.5	$0	$0	$0	$0	$0	$0	$0

Table 4. Amount of additional Flexi N required to achieve the optimal yield

Additional Flexi N to reach optimum yield (l)

Yield (t/ha)	Protein 8.5%	Protein 9%	Protein 9.5%	Protein 10%	Protein 10.5%	Protein 11%	Protein 11.5%
3.5	315	263	210	158	105	53	0
4	263	210	158	105	53	0	0
4.5	210	158	105	53	0	0	0
5	158	105	53	0	0	0	0
5.3	105	53	0	0	0	0	0
5.6	53	0	0	0	0	0	0
5.8	0	0	0	0	0	0	0

zones in a field where the protein is less than 11.5 percent and the yield is average or less than average, then a positive yield response can be achieved by applying more nitrogen.

Using an approximate factor of 0.6 t/ha yield response per 100 litres of nitrogen per percent protein allows the farmer to compute how much nitrogen should be applied to achieve the optimum yield. Table 4 shows this simple computation.

The other benefit of using the protein/yield correlation quadrant maps is that it makes implementation of VRF simple. The four performance zones; green, blue, red and yellow, show how the plants have accessed and taken up nitrogen from the soil. The green zones are the sweet spots in the field where the plants have achieved their full yield potential. the blue zones are most likely water limited. The red and yellow zones are where the plants were nitrogen limited at some stages in the growth cycle.

As such, a VRF prescription can be developed where the rate of nitrogen fertiliser is held constant in the green zones and increased in the red and yellow zones. These zones are where the low-lying fruit can be gathered, and a positive yield response can be achieved.

The implementation of VRF becomes very simple and will ensure positive results. The blue zones are where there are other factors affecting the plants growth. Further investigation may be required, ie soil pits, to understand what is limiting the plants growth in these zones.

Conclusion

Researchers and agronomists have been aware of the significance of protein in developing VRF nitrogen applications, however there has not been available an instrument to measure the seed protein and therefore the nitrogen availability and uptake across the field. The CropScan 3300H On Combine NIR Analyser is the missing piece of the precision agriculture puzzle. By combining protein and yield with GPS coordinates, a complete picture of the nitrogen availability and uptake can now be achieved.

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