The Next Major Tool for Precision Agriculture: Real-time Protein Monitoring

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Introduction:

It has been forecast that the world will need to increase the production of grains and oilseeds by 30% by 2050 in order to feed the 9 billion people that will inhabit the planet. A major tool available to the agriculture eco system to achieve this task is Precision Agriculture. The US Dept of Agriculture defines of Precision Agriculture as:

" a management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield, for optimum profitability, sustainability, and protection of the environment (adapted from Precision Ag. 2003)."

This article describes the Missing Piece of the PA Puzzle: Protein Monitoring, as the next big PA technology improvement.

History of PA:

The history of Precision Agriculture goes back to 1990 when GPS became available for public use. Since then the major technology milestones include Yield Monitors, Auto steering, Controlled Traffic, Touch Screen Computers and Moisture Sensors. The end game for Precision Agriculture is Variable Rate Fertilization applications for nutrients including Nitrogen, Sulphur, Potassium and Phosphorous, yet so few farmers have adopted VRF technologies. The next piece of the PA Puzzle, i.e., On Combine NIR Analysis, offers a simple solution to the generation of VRF prescriptions based on using protein and yield maps to identify zones where plant growth and development has been limited by the amount of nutrients applied to the plants in the form of fertilizers.

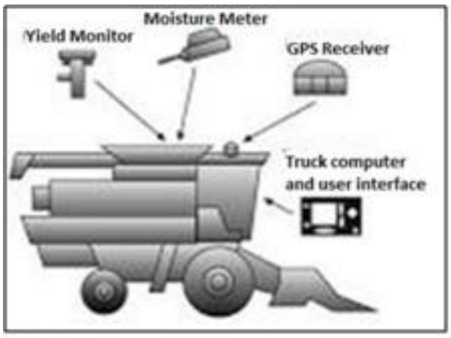

Fig. 1. Implementation of PA on combine harvesters since 1990.

Description:

On Combine NIR Analysis is a technology whereby protein, moisture and oil in grains and oil seeds are measured in real time as the combine harvests the grain from the field. Proteins are composed of Carbon, Hydrogen, Nitrogen, Sulphur and Oxygen. Specifically proteins contain approximately 17.5% Nitrogen. As such for every tonne of grain or oil seeds harvested from the field between 15 and 35kg of Nitrogen is removed from the soil in the form of protein in the seeds.

Based on these relationships between Protein and Nitrogen in the seeds, then the Cropscan 3300H On Combine NIR Analyser provides a means of measuring Nitrogen availability and uptake across the field.

Figure 2 shows the growth stages of cereal crops such as wheat and barley. Nitrogen is required at all stages of the plant growth cycle and the majority of the Nitrogen is taken up during the Stem Elongation and Leaf Formation stages. However soil Nitrogen is critical at the Emergence stage because the plant needs Nitrogen for Tiller production. The number of Tillers should be between 6 and 8 in a healthy plant. If there is insufficient Nitrogen available in the

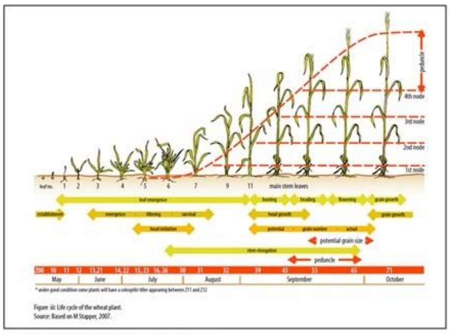

Fig 2. Growth Cycle of Cereal Grains

soil at the Tillering stage, then the plant will produce less Tillers, i.e. 2 - 4. The number of Tillers dictates the number of stems and thereby heads of grains. Once the plant reaches the Stem elongation stage, then the plant cannot produce more Tillers or stems. The Yield Potential is set by the number of Tillers that grow to produce stems and heads, and no amount of Nitrogen is going to increase the Yield beyond what can be achieved through the available Tillers. As the stems grow and leaves emerge Nitrogen and Sulphur are required in the process of photosynthesis to produce sugars which the plant needs to drive cell production and thereby biomass. The Flowering stage is where the heads emerge and are pollinated. If there is insufficient Nitrogen available at this stage the plant may abort some heads in order to ensure that whatever Nitrogen is available will be used to see seeds grow and release. The last stage is the Filling of the seeds. If there is enough Nitrogen available then the seeds will fully develop with starch and protein. If there is excess Nitrogen then the plant will direct the Nitrogen towards producing protein.

If there is enough water available throughout the growth and development stages then the Yield and the Protein will be determined by the availability and uptake of nutrients of which Nitrogen is the most important.

Protein/Nitrogen/Yield Balance:
Protein is related to Nitrogen as discussed above, however the relationship between Protein and Yield is not so obvious. In 2013, Greg McDonald and Peter Hooper, University of Adelaide, School of Agriculture, wrote an article for the GRDC titled: Nitrogen Decisions – Guidelines and rules of thumb. They referenced a paper written in 1963 by JS Russell for the Australian Journal of Experimental Agriculture and Animal Husbandry where he “described the idea of using grain protein concentration to assess the likelihood of N responsiveness in wheat cropping systems. He suggested that yield responses were most likely when grain protein concentration was < 11.4%”. McDonald and Hooper went on to say, “Based on recent trial data, the general conclusion still appears valid: 100% of all trials where grain protein concentration of the unfertilised control was <8.5% were responsive to N and would have given yield response of 14kg/kg N. When grain protein concentration was >11.5%, only 32% of the trials were responsive to N and the mean yield response was zero”. They concluded; “While this relationship can’t be used to make in-season N decisions it may be useful in helping to assess the degree of N stress during the previous season and making post-harvest assessments of N management strategies, which can help in future plantings.”

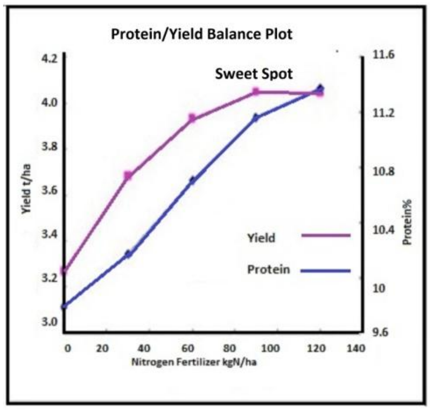

Fig 3. Grain yield (t/ha) and protein concentration (%) from 10 wheat varieties with 0, 30, 60, 90 and 120 kg/ha applied nitrogen in a trial at Parkes in 2011. (Brill et al, 2012, Comparison-of-grain-yield-and-grain-protein-concentration-of-commercial-wheat-varieties)

Protein/Yield Correlation:

Figure 4 shows four scenarios for the relationship between Protein and Yield. The possible explanation for these scenarios are:

- Low Yield + Low Protein = Insufficient Nitrogen throughout all growth stages
- Low Yield + High Protein = Insufficient Nitrogen in the Tillering stage but sufficient Nitrogen in the Flowering and Filling stages. However there may be some other issues limiting yield apart from Nitrogen.
- High Yield + Low Protein = Sufficient Nitrogen in the Tillering and Stem Elongation stages but insufficient Nitrogen in the Filling stages
- High Yield + High Protein = Sufficient Nitrogen throughout all growth stages. This is the “Sweet Spot” where there has been sufficient Nitrogen available at the Tillering stage as well as the Flowering and Filling stages.

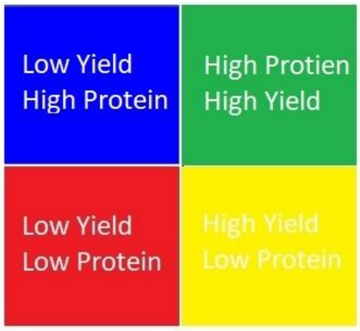

Fig 4. 4 Protein/Yield Correlation Scenarios

Based on these four scenarios, a field can be mapped by the correlation between Protein and Yield. Figure 5 shows the Protein and Yield maps for a wheat field in Young NSW. Figure 6 shows the Protein/Yield Correlation map which plots the correlation between Protein and Yield within a 25m radius. The plot has four colours, i.e. Blue: Low Yield/High Protein, Red: Low Yield/Low Protein, Green: High Yield/High Protein, Yellow: High Yield/Low Protein. The Green areas in the Correlation map are the “Sweet Spots”, i.e. High Yield and High Protein. However the Red, Blue and Yellow areas have performed poorly.

According to the experts referenced above, the Yellow and Red areas would most likely have responded to additional Nitrogen fertilizer being added. Wherever the Protein levels in the finished grain were below 11.5%, then the crop did not reach its full Yield Potential. For the 2017 crop, 2017, the farmer applied a simple Variable Rate Fertilization strategy as follows:

Protein < 11.5% = 120kg/ha
Protein 11.5 – 12.5% = 80kg/ha
Protein > 12.5% = 60kg/ha

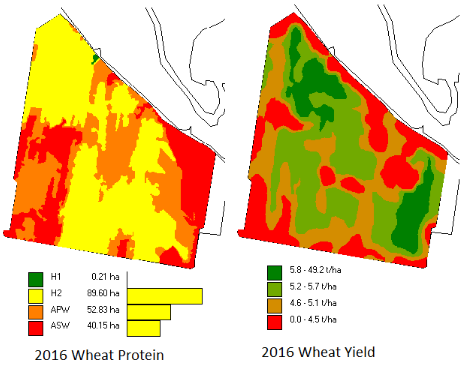

Figure 5. Protein and Yield Maps,

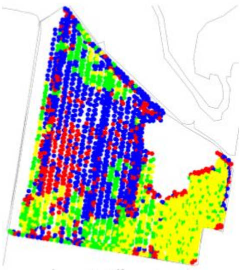

Fig 6. Protein/Yield Correlation Map

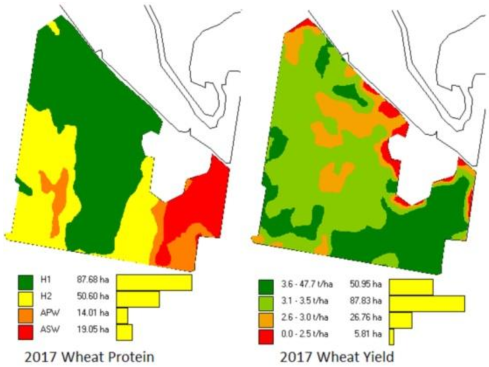

Fig 7. Protein and Yield Maps, 2017

Figure 7 shows the Protein and Yield maps for the 2017 wheat crop. It can be seen that the majority of the crop had jumped a protein grade, i.e., APW to H2 and H2 to H1. The farmer calculated that the Yield variation had been reduced by 40% across the field as compared with 2016, and that the average yield was 0.4Tonne/ha more than the local average. Based on the increase in Protein payments and Yield, the farmer reported that he made an additional $2482 or $13.61/ha in this field alone through the use of the CropScan On Combine Analyser and the subsequent VRF strategy from the 2016 maps.

Discussion:
If the drawback for VRF technology lies in the complexity of the maps and the interpretation of the many layers of data, then On the Go Protein analysis using an On Combine NIR Analyser provides a very simple means for farmers and their agronomists to capture 20-30% Yield improvements. The "Low hanging fruit", i.e., the first 20-30% Yield improvements are not the end of the story. Protein plus Yield tells the complete story as to the availability and uptake of nutrients including Nitrogen, Sulphur, Potassium and Phosphorus. The CropScan 3300H On Combine Analyser adds several layers of agronomic data that has been missing from the PA puzzle.

Michael Eryes, Field Systems Australia, SA, stated:
"The Yield map correlates directly to soil performance and the Protein map is a very good proxy for plant performance. The Nitrogen data is what makes everything else fit together, i.e., productivity and performance. The on combine protein analyser is a tool of exceptional value whose true value is only just starting to be well enough understood"

References:
1. Russel JS, Nitrogen contents of wheat grains as an indication of potential yield response to nitrogen fertilizer.. Australian Journal of Experimental Agriculture and Animal Husbandry, 3:319-375

2. McDonald G, Hooper P., GRDC Nitrogen Decision – Guidelines and Rules of Thumb. University of Adelaide, School of Agriculture, Food and Wine. Adelaide, SA, Australia.

3. Nitrogen for Winter Wheat – Management Guidelines, HGCA is a division of the Agriculture and Horticulture Development Board (AHDB). 2009

4. Michael Eyres, Field Systems, Adelaide, SA, Personal correspondence.