Real-time protein monitoring

The next major tool for precision agriculture

by Philip Clancy, Next Instruments, Australia

Cereal and oil seed crops including wheat, barley, rice, corn, canola and soybeans make up more than 80 percent of the world's grain production, i.e., 2,513 million metric tonnes in 2017. It has been forecast that the world will need to increase the production of grains and oilseeds by 30 percent by 2050 in order to feed the nine billion people that will inhabit the planet.

However, there is not an additional amount of arable land to meet this demand. As such farmers, agronomists, agricultural scientists and governments are faced with the challenge of producing 30 percent more through better technology.

A major tool available to the agriculture eco system to achieve this task is precision agriculture (PA). The US Department 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)."

Since 2008, there has been approximately a 10 percent increase in production shown in the following plot of annual gross grain production. So what is the next big step in PA that will sustain this growth rate?

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. (See Figure one).

The end game for precision agriculture is variable rate fertilisation (VRF) applications for nutrients including nitrogen, sulphur, potassium and phosphorus, yet so few farmers have adopted VRF technologies.

The most likely reason for the low uptake of VRF technologies is that there have been few examples of success that can be credited to PA. It could also be argued

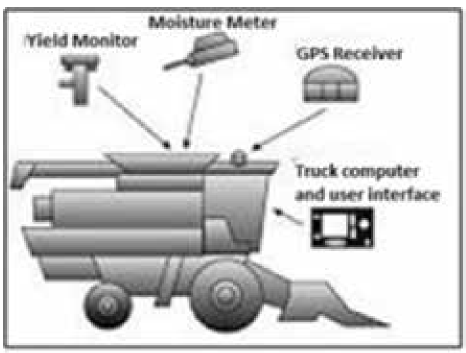
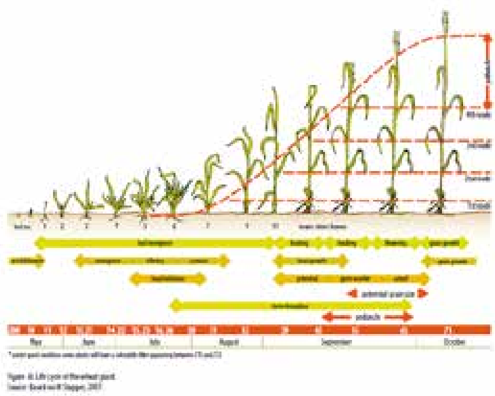
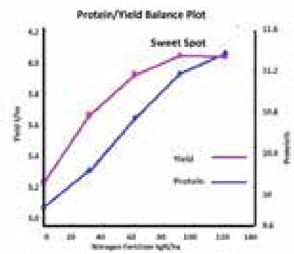


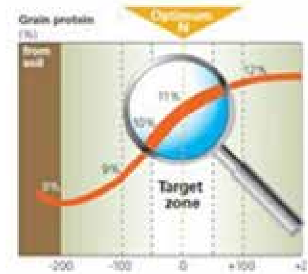
Fig. 1. Implementation of PA on combine harvesters since 1990.



that farmers find it too complex to translate data taken from their PA tools and create VRF prescriptions to use on seeders, spreaders and sprayers.

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.





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 percent nitrogen and 3.5 percent sulphur by weight.

As such, for every tonne of grain or oil seeds harvested from the field between 15 and 30kg of nitrogen and 3 and 7 kg of sulphur are removed from the soil in the form of protein in the seeds. Based on these relationships between protein and nitrogen and sulphur in the seeds, then the On Combine NIR Analyser provides a means of measuring nitrogen and sulphur availability and uptake across the field.

Moisture is the major factor that influences plant growth and development, however, nitrogen is the most important nutrient that is required by plants in order to fully grow and produce seeds. Figure two 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 six and eight in a healthy plant. If there is insufficient nitrogen available in the soil at the tillering stage, then the plant will produce less tillers, i.e. between two-to-four.

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 from the University of Adelaide's 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 percent".

McDonald and Hooper went on to say, "Based on recent trial data, the general conclusion still appears valid: 100 percent of all trials where grain protein concentration of the unfertilised control was <8.5 percent were responsive to N and would have given yield response of 14kg/kg N. When grain protein concentration was >11.5 percent, only 32 percent of the trials were responsive to N and the mean yield response was zero".

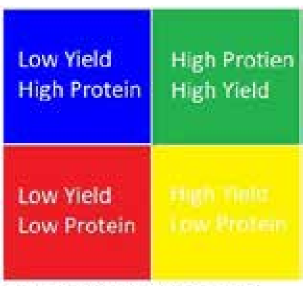


Fig 4. 4 Protein/Yield Correlation Scenarios

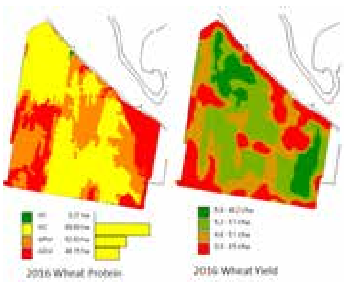


Figure 5. Protein and Yield Maps,

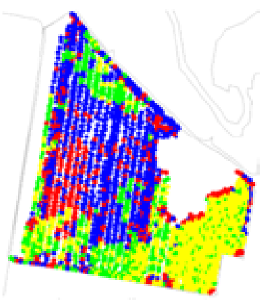


Fig 6. Protein/Yield Correlation Map

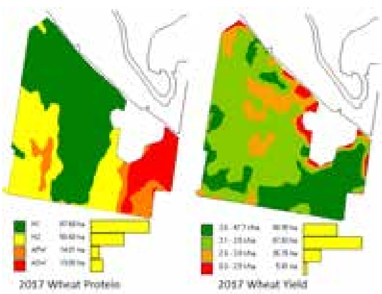


Fig 7. Protein and Yield Maps, 2017

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."

Other scientists and agronomists have written about the relationship between protein content of the finished grain and the yield. Steve Larocque, Beyond Agronomy, Canada, publishes a newsletter that is read by more than 8000 precision farmers and agronomists around the world.

Mr Larocque pointed out in his newsletter that there is a fine balance in applying nitrogen to a barley crop where the objective is to optimise the yield and restrict the protein to less than 13 percent. He states, "The hard part is finding the right nitrogen rate to produce maximum yield with a protein that falls below 13 percent but higher than 12 percent. When your malt protein is lower than 12.5 percent you know you're leaving yield on the table. If you shoot too high you end up with high protein and no malt selection."

Mr Larocque referred to the balance as the "sweet spot" where the yield was optimised and the protein grade realised the highest crop payments.

Thane Pringle, Independent Precision Agriculture, Yenda, NSW, explains how nitrogen is used by plants and how nitrogen is made available from the soil to the plants. He showed a plot (see figure three) of yield vs nitrogen fertiliser application vs protein content of the grain. Brill et al state in their original paper, "As the rate of N supply is increased, yield will generally increase to a maximum level, whereas protein may continue to increase with further N application. This is demonstrated by the results from a trial at Parkes in 2011, sown as part of the GRDC-funded Variety Specific Agronomy Project.

"Wheat yield was responsive to N fertiliser but at a reducing rate where N was applied in 30 kg/ha increments. Yield was maximised with N application of 90 kg/ha. Protein increased linearly for each 30 kg/ha increment up to 120 kg/ha N. In this trial, yield appeared to be maximised at a grain protein concentration of 11.2 percent, a useful 'rule of thumb' in deciding whether a crop was yield limited by N."

Professor Roger Sylvester-Bradley, UK, in a HGCW booklet titled Nitrogen for Winter Wheats—Management Guidelines, wrote, "Grain protein with optimum N for yield in feed varieties is consistently about 11 percent (1.9 percent N). Bread making varieties optimise for yield at around 12 percent protein and often need extra N to achieve a market specification of over 13 percent. Low grain protein – less than 10 percent for feed varieties – Indicates sub-optimal N use." (See figure four).

Protein/yield correlation

Figure 5 shows four scenarios for the relationship between protein and yield.

The possible explanations 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.

Based on these four scenarios, a field can be mapped by the correlation between protein and yield. Figure 6 shows the protein and yield maps for a wheat field from Broden Holland's farm in Young NSW. Figure 7 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 fertiliser being added. Wherever the protein levels in the finished grain were below 11.5 percent, then the crop did not reach its full yield potential.

For the following crop, 2017, the farmer applied a simple variable rate fertilisation strategy as follows:

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

Figure 8 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 percent across the field as compared with 2016, and that his yield was 0.4 tonnes/ha more than the local average.

Based on the increase in protein payments and yield, the farmer reported that he made an additional US $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.

Another example is from Leeton Ryan, Woomalang, Victoria, who fitted a CropScan 3000H Grain Analyser to a CaseIH 8240 combine in the 2016. The 3000H records protein, moisture and oil, along with the longitude and latitude every 8-12 seconds as the combine strips the grain.

The yield data was collected from an on board yield monitor. He also collected data for elevation which showed the undulating terrain on his farm. Figure 9 shows the various maps generated for this one wheat field. Based on the 2016 maps, Leeton determined three zones in the field whereby he could apply nitrogen in the form of urea at rates related to the amount of nitrogen removed from the field.

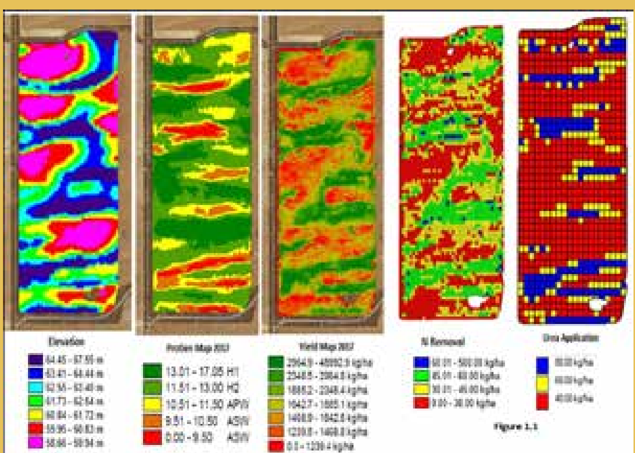
Urea application (kg/ha)
Blue zone: Protein < 10.5 = 80 kg
Yellow zone: Protein < 11.5 = 60 kg
Red zone: Protein < 13.0 = 40 kg

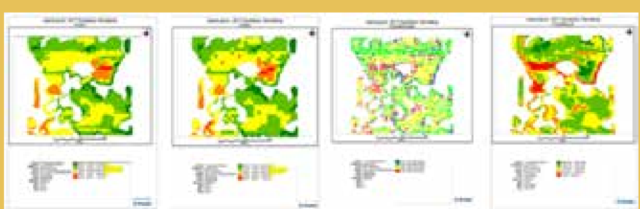
Leeton's objectives are to use this simple VRF strategy to top dress his fields so that he could increase the yield and protein payments.

A third example is from Adam Gurr, Brandon, Manitoba, who installed a CropScan 3000H in 2017 onto his Claas Lexion combine. His soybean maps provide examples of how protein varies in crops other than cereals. Figure 10 shows maps for protein, yield, protein/yield correlation and a VFR prescription for nitrogen prescription based on these maps.

The protein varied across this field from 20 percent to 37 percent with an average of 32 percent for the loads delivered to the local elevator. It is generally expected that soybeans will exhibit an inverse relation between Yield and Protein, i.e. the Dilution Theory.

Figure 10, the yield/protein correlation map, shows areas in the field based on the correlation between protein and yield. The green and red areas do not follow the Dilution Theory. The yellow areas are where the yield was above the average for the field and the protein was less than the average. In the yellow areas, it is suggested that by increasing the nitrogen fertilisation rate would increase yield and protein.





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 percent yield improvements.

The "low hanging fruit", i.e., the first 20-30 percent 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, states,"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."

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