Tech Note 0100: Research Supporting the Protein/Yield Correlation Quadrant Map Theory for Determining Crop Performance Zones and Variable Rate Nitrogen Fertilization Applications

Introduction:

In 2017, Thane Pringle[1], an agronomist from Independent Precision Ag, Griffith, NSW, made a presentation on the growth of cereal crops. Within his talk, he introduced a concept that was well established in agriculture science but poorly recognised by agronomists and farmers. Mr Pringle pointed out that as a cereal plant grows it will reach its optimum yield if all the nutrients and water are available to the plant during the growth cycle. Once the plant reaches the optimal yield, then any excess Nitrogen available to the plant is used to produce more protein in the seeds. Moreover the yield reached its maximum at approximately 11.5% Protein. He gave a thorough explanation of how the plant grows and when and where Nitrogen is taken up by the plant. He concluded his presentation by explaining why in-field Protein measurements are crucial to understanding Nitrogen Availability and Uptake across the field and how this information leads to a more accurate and reliable means of developing Variable Rate Nitrogen Fertilization Applications.

Since then I have been looking for research around the world that supports Mr Pringles discussion. This technical Note provides references to several studies undertaken around the world on the relation ship between Protein and Yield. It also attempts to explain how the Protein/Yield Correlation Quadrant Map tool ,that is available through the CropScanAg N-GAUGE Nutrient Manager App, can provide accurate and reliable VRF Prescription Maps for grain farmers.

Results:

Article 1: In 1963, JS Johnson[2], published a paper in 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%".

Article 2: In 2003, D.B. Fowler, Crop Dev. Centre, University of Saskatchewan, reported his finding in a paper titled, "Crop Nitrogen Demand and Grain Protein Concentration of Spring and Winter Wheat." He investigated the effect of Nitrogen fertilizer application on GPC (Grain Protein Content) and Yield in a range of cultivars of wheat. Although his objectives were to understand the impact on GPC, his paper presents plots of the relationship between Yield and Nitrogen application as well. He found that in all cases the yield reached a maximum at approximately 120kg/ha N application rate. However he found that the GPC at which the maximum Yield were achieved varied from 8.8% for Stephen's Soft White Wheat to 13% for Norstar Winter Wheat.

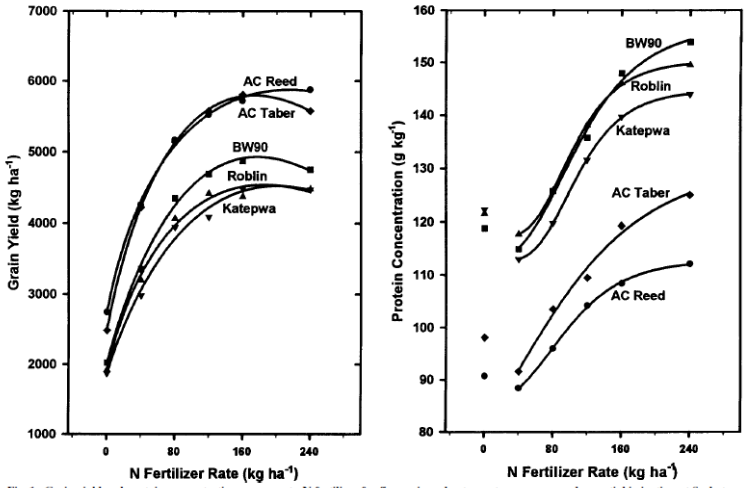

Fig. 1. Grain yield and protein concentration response to N fertilizer for five spring wheat genotypes grown under partial irrigation at Saskatoon in 1994. The peak four-parameter Weibull equation was employed to describe the grain yield response, and the sigmoidal four-parameter Gompertz equation was used to describe the grain protein concentration response to N fertilizer applications.

Article 3: In 2009, Professor Roger Sylvester-Bradley[3], 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% (1.9%N). Bread making varieties optimise for yield at around 12% protein and often need extra N to achieve a market specification of over 13%. Low grain protein – less than 10% for feed varieties – Indicates sub-optimal N use."

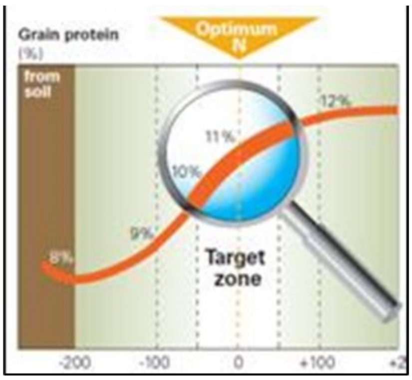

Figure 2. Nitrogen For Winter Wheats—Management Guidelines, Sylvester-Bradley, 2009

Article 4: In 2011, Brill et al[4], published an article, “Comparison-of-grain-yield-and-grain-protein-concentration-of-commercial-wheat-varieties). The graph, Fig 1. shows the relationships between Yield and N fertilizer rate and Protein and N fertilizer rate. Both Yield and Protein increase with the additional fertilizer application, however Protein continues to increase where as Yield plateaus at approximately 11.3% Protein.

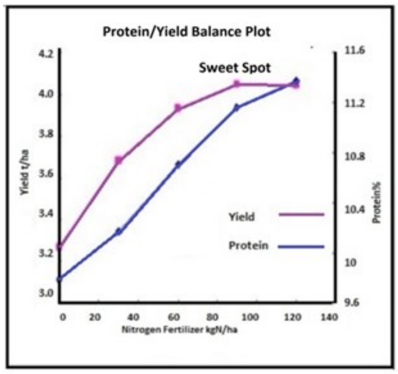

Figure 3. Grain yield (t/ha) and protein concentration (%) from 10 wheat varieties with 0, 30, 60, 90 and 120 kg/ha applied nitrogen in a trial at Parkes in 2011.(Brill et al, 2012, Comparison-of-grain-yield-and-grain-protein-concentration-of-commercial-wheat-varieties).

Article 5: In 2013, Greg McDonald and Peter Hooper[5], University of Adelaide, School of Agriculture, wrote an article for the GRDC titled: Nitrogen Decisions – Guidelines and rules of thumb. They said, “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.”

Article 6: Steve Larocque[6], Beyond Agronomy, Alberta, 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 optimize the yield and restrict the protein to less than 13%. He states, “The hard part is finding the right nitrogen rate to produce maximum yield with a protein that falls below 13% but higher than 12%. When your malt protein is lower than 12.5% 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 optimized and the protein grade realised the highest crop payments.

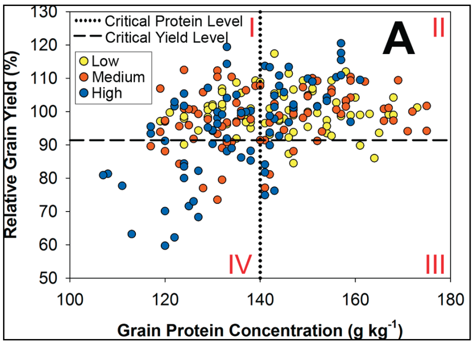

Fig. 4. Relative grain yield vs. grain protein concentration of hard red spring wheat. Duplicate plots show data points that are color-coded to highlight (A) three water and (B) five N levels. Critical yield level (centre dashed line) and critical protein level (centre dotted line) were determined by the Cate–Nelson procedure.

Article 7: In 2017 Long et al[7], published a paper in Soil Fertility and Crop Nutrition where they found. “Studies in the northern Great Plains revealed that GPC below a critical level is usually associated with below maximum yields indicating a N fertility deficiency (Goos et al., 1982; Engel et al., 1999; Selles and Zentner, 2001). Critical protein concentrations for HRS wheat have been determined to be 140 g kg–1 in North Dakota (Goos, 1984), 135 g kg–1 in northern Montana (Engel et al., 1999), and 128 g kg–1 in southern Saskatchewan (Selles and Zentner, 2001). Selles and Zentner (2001) found that GPC as an indicator of N sufficiency works well when water is not limiting and N availability controls yield and GPC. They concluded that GPC below a critical level is a reliable indicator of N deficiency, but high GPC does not necessarily imply N sufficiency because high protein can occur under water stress.

Article 8: In , Eva Moffitt[8], presented a FarmLink Research Report titled; Utilising new technologies to better manage within paddock Nitrogen variability and sustainably close the Yield Gap in Southern NSW”. Ms Moffitt conducted trials across 5 farms in southern NSW. She commented, “While it has been shown that both varietal and climatic conditions can influence critical grain protein concentrations (Fowler, 2003), a simplified ‘rule of thumb’ interpretation is that wheat with <11.5% grain protein has had insufficient nitrogen to optimise yield, whereas wheat with >11.5% grain protein has had surplus nitrogen, which has been used to increase protein, often with no economic gain.”

Protein/Yield Correlation Quadrant Maps Theory:

Associate Professor Brett Whelan[9], Precision Agriculture Laboratory, The Sydney University, Sydney, Australia, introduced the concept of Protein/Yield Correlation Maps in 2015. His maps showed the correlation between Protein and Yield in the form of three zones, i.e., Negative Correlation, Positive Correlation and Zero Correlation. An example of Professor Whelan's map is shown in figure 5. The theory is that a positive correlation indicates that the Nitrogen application was sufficient to achieve both high Yield and high Protein. Where as a negative correlation indicates zones where the Nitrogen application or water availability limited Yield or Protein.

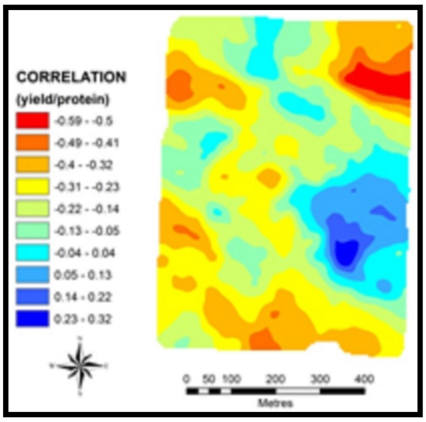

Figure 5. Protein/Yield Correlation plot for a wheat field on the York Peninsula, SA.

A refinement of the above correlation maps was developed by CropScanAg in 2016 by considering that a positive correlation can be High Protein and High Yield or Low Protein and Low Yield. Figure 6 shows the possible zones that can be identified using a four quadrant map.

- The Green Zone is referred to as the Sweet Spot where the Nitrogen application has been sufficient to achieve the optimum Yield and Protein in the crop.
- The Red Zone is where there has been insufficient Nitrogen available through the growth period to achieve optimum Yield nor Protein.
- The Yellow Zones is where there was sufficient Nitrogen to achieve Yield but not enough to achieve Protein.
- The Blue Zone is where the Nitrogen application was sufficient to achieve the Protein but other factors limited the Yield.

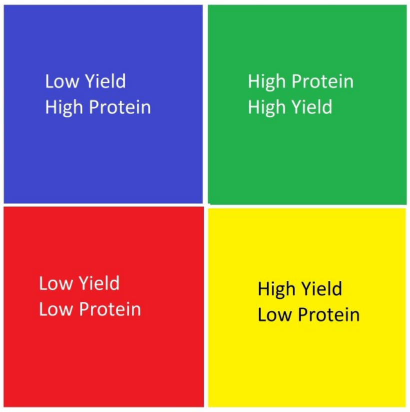

Figure 6 . Protein/Yield Correlation Quad-

The Protein/Yield Correlation Quadrant Map for a wheat field is shown in figure 7. The interpretation for this map is that more Nitrogen can be applied to the Yellow and Red zones to increase Yield and Protein. Soil tests can be undertaken in the Blue zones to see why the Yield was limited. The Green zones are where the Nitrogen application rate was sufficient, if not too much.

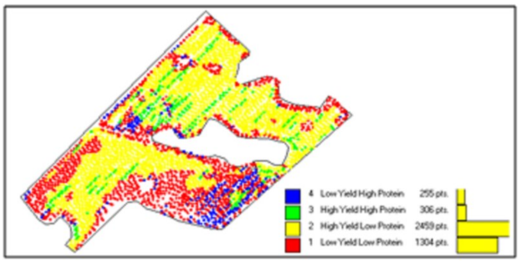

Figure 7. Protein/Yield Correlation Quadrant Map for a wheat field in Esperance, WA, Australia.

Variable Rate Nitrogen Prescriptions can be generated by simply increasing the Nitrogen application rate over the previous blanket rate in the Red and Yellow zones, maintaining the rate in the Green zones and reducing the rate in the Blue zones. The amount of the increase was determined by running a strip trial in this field at rates of 0, 50, 100, 150 and 200l/ha of FlexiN fertilizer as shown in figure 8. It shows that 100l of additional fertilizer produced an extra 1 tonne of Yield. It was also determined that 100l of fertilizer increased the Protein content by 0.9%. As such, where the Protein content of the wheat was low then an additional 100kg of FlexiN could be added per hectare for every .9% below 11.5%.

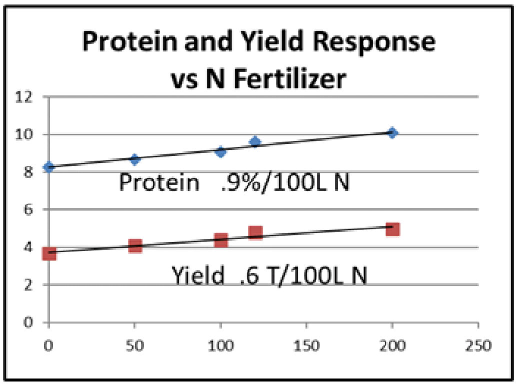

Figure 8. Plot of Yield and Protein vs Nitrogen Rate for a strip trial on a wheat field in Esperance, WA, Australia.

The N-GAUGE Nutrient Manager App includes a Prescription Creator tool that automatically determines the Variable Rate Fertilization Prescription rate across the field. The recommended VRF rates are shown in grids. The farmer and their agronomist can click on each grid and change the rate based on their local knowledge or preferences. Once the prescription has been settled, the map can be posted to the CropScanAg Cloud Server and then sent to the farmers combine manufacture's platform, i.e., CNHI AFS or PLM or John Deere's Operation Centre.

Discussion:

Proteins are made up of Amino Acids which contain approximately 17.5% Nitrogen by weight. As such, measuring Protein in grain as it is harvested and combining it with the Yield, is a direct measurement of how much Nitrogen is being removed from the soil in the form of Protein in the seeds, i.e., Nitrogen Uptake or Nitrogen Removal. By understanding why a plant has achieved the Yield and Protein levels, explains the Nitrogen Availability to the plant.

For example: If the Nitrogen is leached down into deeper layers of soil due to rainfalls shortly after fertilization, then the plants may not have sufficient Nitrogen available to sustain the full development of the tillers. If some tillers are aborted by the plant in order to optimize the chance of the plant reaching maturity, then the Yield Potential will have also been reduced. If the plant's roots grow deep enough to access the leached Nitrogen, then there will be sufficient Nitrogen in the flowering and filling stages of growth so that the heads grow to their full potential. Any excess Nitrogen will then go to produce Protein. However the Yield potential was set by the number of tillers that were left to grow on the plant. This example may be the cause for a Blue zone scenario.

The four quadrants in the Protein/Yield Correlation Quadrant Maps can help farmers to access the crop performance in each zone. Based on the performance, they can develop VRF Prescriptions that directly address the issues the crop faced in each zone.

References:

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