# Measuring Nitrogen Uptake and Availability in the Field

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## Introduction:

Nitrogen is one of the major nutrients in plant growth and development. Measuring Nitrogen in soil provides farmers with a means of predicting the yield for a crop, however soil testing is a costly and time consuming procedure. Measuring Nitrogen Uptake in the plants provides farmers with a layer of information that helps them to understand how the plants have performed and how much Nitrogen from the soil ended up in the seeds. Protein can now be measured in real-time as grain is harvested. An on combine NIR analyser measures the protein in the grain which is directly related to the amount of Nitrogen taken from the soil. By combining the yield data with the protein data then a more complete understanding of the impact of Nitrogen fertilization can be achieved across the field or paddock. This article describes how measuring protein in real time using an On Combine NIR analyser is related to the Nitrogen availability in the soil.

## When does the Plant need Nitrogen?

As the seed sprouts and the first shoots appear through the soil, the plant needs Nitrogen in order to develop tillers. For wheat crops, between 330-400 tillers per square meter should be evident. This means around 6-8 tillers per plant should be growing. If there is not enough Nitrogen present as nitrate ions in the soil at this early stage then the crop will never achieve an optimum yield because there will not be enough heads produced. If there is sufficient Nitrogen present then the plant should produce the 6-8 tillers. The schematic below shows the growth phases for spring wheat.

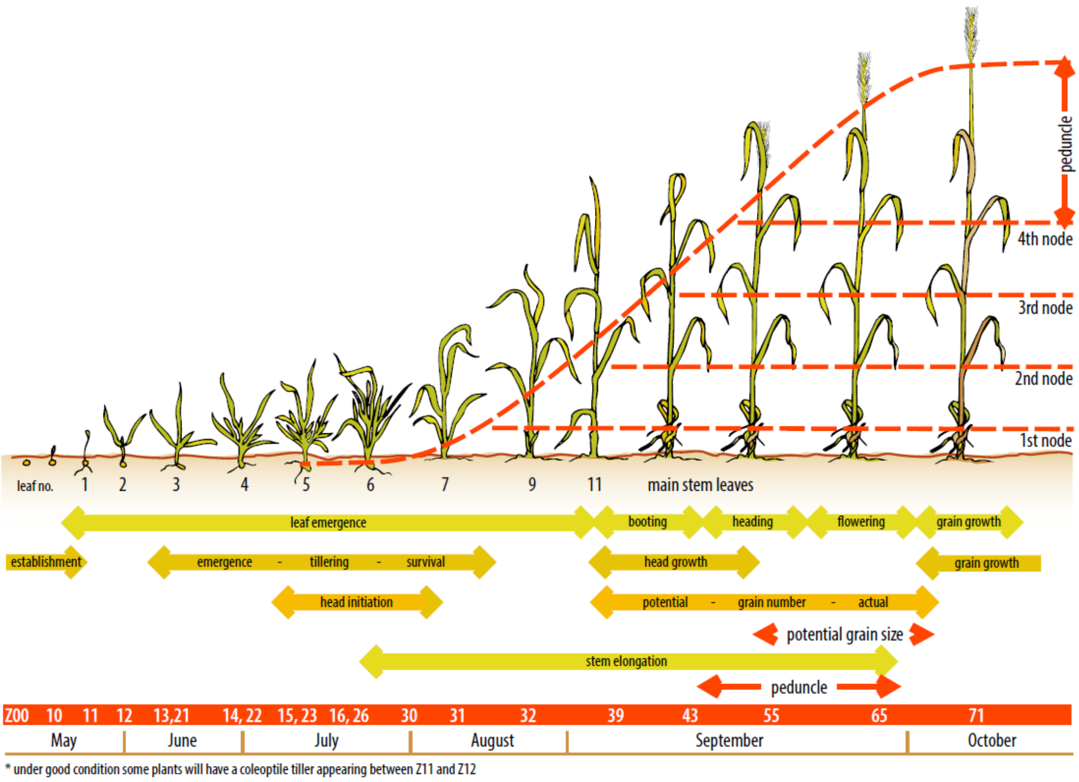



Figure iii: Life cycle of the wheat plant.
Source: Based on M Stapper, 2007.

You can add more Nitrogen during the tillering phase, but once the plant has finished tillering, then no new tillers will grow, and some may die, thus fixing the number of heads that can be produced and therefore the yield potential. An agronomist recently advised that you cannot recover the yield loss due to insufficient tillers by adding more Nitrogen once the tillering has completed.

As the plant continues to develop, the leaves capture energy from the sun and through the process of photosynthesis creates the starch and sugars required for vegetative growth, i.e., biomass production. Insufficient Nitrogen in the vegetative growth phase will result in yellowing and stunted leaf growth. As such the leaves capture less light and produce less energy for growth and development.

Adequate Nitrogen in the later stages of growth increases the length of time the canopy stays green, provided moisture is not limiting, and thus maximises photosynthesis. This in turn makes available more starches and sugars for use in the Flowering and Grain Filling phases. Adding extra Nitrogen in the later stages of the growth phase will allow the plant to reach its full yield potential and produce protein as long as there is sufficient soil moisture.

During the Flowering phase, the plant requires moisture and nutrients in order to produce the maximum number of grains per head. Stress caused by lack of soil moisture or Nitrogen will cause the plant to reduce the number of grains per head and to maximize the available carbohydrates to fully produce the heads. The plant may also abort some heads. The net result is a decrease in yield because there are fewer grains per head and less heads to be filled during the Grain Filling phase.

In the Grain Filling phase, any stored Nitrogen will go to produce protein. If there are fewer grains per head and less heads per plant then the stored Nitrogen will be distributed amongst the available heads and therefore will increase the protein content. If the plant is not under stress and there is sufficient soil moisture but not enough Nitrogen then the yield will be high and the protein will be low. If there is sufficient soil moisture and sufficient Nitrogen then the yield will be high and the protein will be high. As a general rule, applications of nitrogen from sowing to stem elongation increases yield, while applications after stem elongation increase protein.

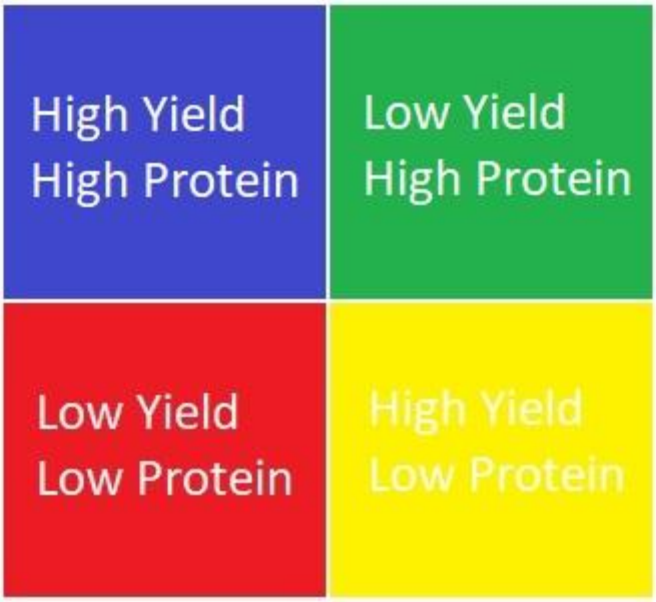
## Relationship between Nitrogen and Protein:

Protein is a generic terms used to characterise a large class of bio molecules that have common chemical characteristics. In truth, proteins are polymer chains formed from Peptides which are made up of Amino Acids. Humans and animals eat proteins so that they can digest the proteins and release the amino acids from them in order to rebuild body tissues, e.g., skin, muscle, organs etc. Plants such as wheat, soy beans, corn, rice etc make amino acids which after digestion in the human or animal gut, then go to make peptides which then go to make proteins.

The proteins found in the seeds of a plant have approximately 16-18% Nitrogen in them. As such for every load of grain stripped from a field, then there is a portion of the load that is protein and Nitrogen. For example, if the protein content of the soy beans is 20% then 200 kg of each tonne of grain is protein. And out of this 200 kg of protein there is 16% Nitrogen, i.e., 32kg. This means that for every tonne of soy beans harvested, 32kg of Nitrogen is removed from the soil. Of course Nitrogen is found in other parts of the plant tissue, but in the majority of plants Nitrogen ends up in the seeds as protein.

## Protein/Yield Correlation:

The chart below shows 4 senarios for the correlation between Protein and Yield. There are four implications for these scenarios as shown below each.




Based on these four scenarios, a field can be mapped by the correlation between Protein and Yield. Figures 3 and 4 are Protein and Yield maps for a wheat field in central NSW. Figure 5 shows the plot of the correlation between Protein and Yield within a 50m diameter. In other words, the correlation, R, for the Protein and Yield collected within 50m diameter circles in the field are plotted for each 50m diameter circle. The plot has four colours, i.e.

Blue – High Protein/High Yield
Green – High Protein/Low Yield
Yellow – Low Protein/High Yield
Red – Low Protein/Low Yield

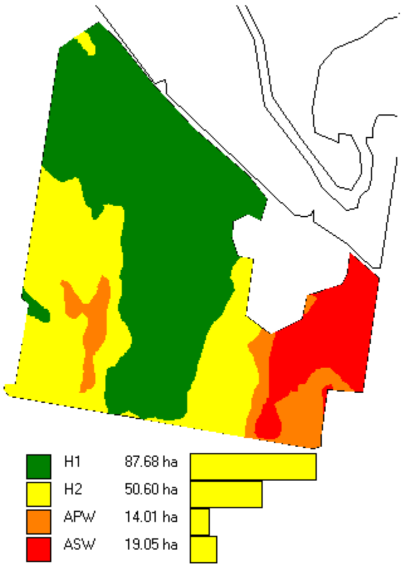



Fig 3. Protein Map

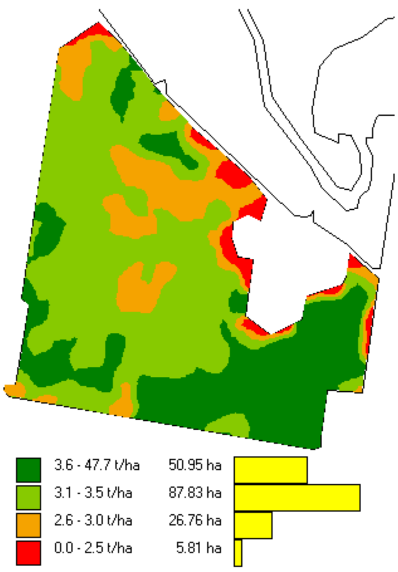



Fig 4. Yield Map

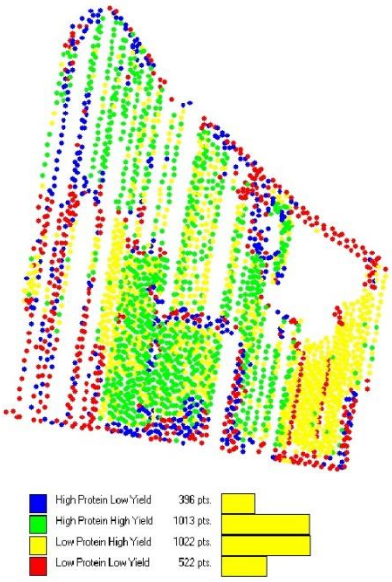


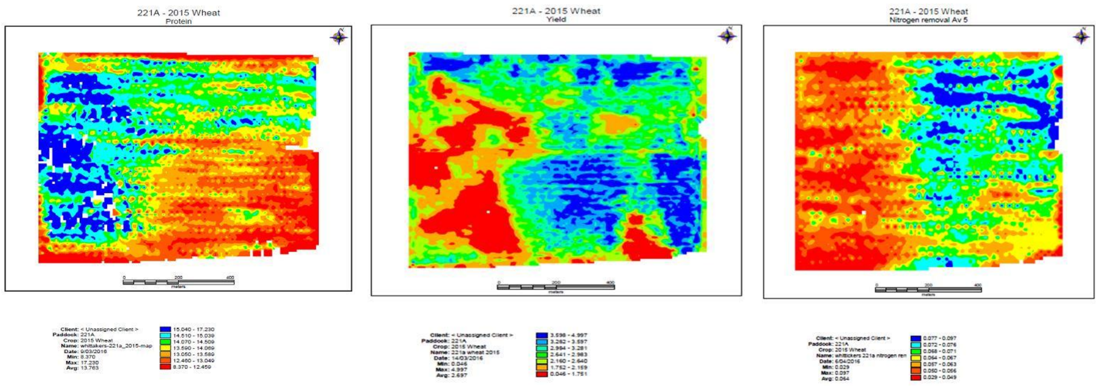

Fig 5. Correlation Map

The Correlation plot provides a map of where to sample the soil for nutrient deficiencies, such as Nitrogen, Sulphur, Potassium and Phosphorous.

The green areas in the Correlation map are the "Sweet Spots", i.e. High Yield and High Protein. The Red areas are the worst for Yield and Protein. Since the fertilizer application was a blanket rate in 2017, the question that must be asked, "Why does 50% of the field produce 3.5tonne per ha where as some areas produce only 2.5 tonne per ha. The answer most likely lies in the soil types in these areas. By examining the soil types and the geography in the Blue, Red and Yellow areas, it may be possible to understand why there was not sufficient Nitrogen available to achieve the optimum Yield and Protein. Next year, this information may be used to try a Variable Rate N Fertilizer application in these areas.

## Nitrogen and Yield tells a more complete story:

Yield maps measure the mass of grain that is stripped per acre or hectare.  Yet for the last 25 years yield maps have been used as a proxy for Nitrogen Uptake because the protein content of the seeds dictates the amount of Nitrogen taken from the soil. In reality yield maps provide a view of how Nitrogen fertilizer effects plant development and growth, but is yield the complete view. In a perfect world there needs to be an instrument that measures the Nitrogen in the soil at the time of planting, during the Stem Elongation and Flowering phases. At this time, there is no instrument that can perform such a measurement in real-time. However there is an instrument that can measure the Nitrogen Uptake in the plant as it is stripped. An On Combine NIR Analyser such as the CropScan 3000H, is designed to measure protein, oil and moisture in grain and oil seeds as the grain is harvested. Since protein is a direct measure of the Nitrogen in the seeds, then this instrument can be used to generate a Nitrogen Removal Map. Figure 3 shows a protein map, a yield map and Nitrogen Uptake map for a wheat field in South Australia.




The yield map shows that there are large areas where the yield is low, i.e., red areas. Based on the yield map, the conclusion would be that more Nitrogen is needed in these areas. However the protein map shows that the same areas had high protein, i.e., blue areas. From the discussion above, it can now be seen that there was sufficient Nitrogen to fill the grain with protein. The yield map and the protein maps appear to be contradictory. The answer is that there was insufficient Nitrogen in the soil at the time of planting and up to the end of the Tiller phase.  However the story is not finished yet.

The yield map shows a large area where the yield is high, i.e., the blue areas.  The protein map shows that these same areas had the lowest protein levels.  This scenario suggests that in these areas the Nitrogen was available for early growth and Tiller development, but there was not enough Nitrogen at the Grain Filling phase.

As well, in these areas the protein levels are less than 10.5%, making it ASW grade.  In 2015 the difference in price between ASW and APW grades was $30/tonne.  A top dressing of Nitrogen towards the later phase of plant growth could have increased the protein levels and thereby raised the grade to APW or even H2. Top dressing at this stage would have increased payment revenues significantly by several thousand dollars for this field.

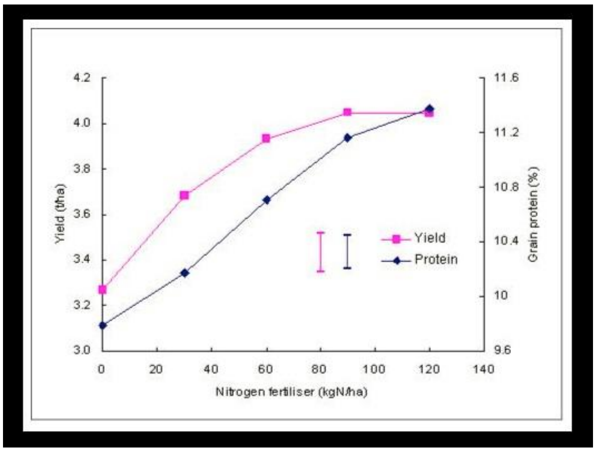
The soil moisture profile, rain fall history, soil types and fertilization history are important factors in understanding what has driven the plant growth in this field.  A look at the Nitrogen Removal map shows that there are three zones, i.e., Red Zone 1: left hand side, Blue Zone 2: top right hand corner, Green Zone 3: bottom right hand corner.  Reviewing the soil types in these three zones may lead to better timing of fertilizer application so that Nitrogen is not leached from the root zones by rain shortly after planting. Reviewing the fertilizer history for the field may show that top dressing towards the end of the growth phase would have ensured fully developed plants followed by complete grain filling.

In the following season, the Nitrogen Removal map could be used to fertilize the field more effectively so that the three zones are more consistent in terms of yield and protein. Although reduction of Nitrogen fertilizer usage may be possible, it is more likely that the fertilizer could be applied more effectively and results in higher yield at the optimum protein grade.

## Protein/Nitrogen/Yield Balance:

The adage "Yield is King" is exactly right. You make more money out of increasing the yield than you do by chasing higher protein wheat. However another statement could be; "Protein is the Cream". If you achieve the optimum yield from your paddock and get the protein grading correct, then you can add significantly to your revenues and profit.

A syndicated agronomist Steve Larocque, Beyond Agronomy, Alberta, Canada, stated in his newsletter that the challenge for farmers is to find the "Sweet Spot" between Yield and Protein in their crops. Barley and wheat, he states, should reach their optimum yield at between 11.0 and 12.0% protein. If the protein is not at this level then the crop will not have reached its full potential yield of approx 4 tonne per hectare.




The graph shows the relationship between yield and protein. The optimum protein level for hard wheat is between 11-12%. If you are not growing wheat at this protein level then you are not achieving the optimum yield. Since APW grade requires a protein above 10.5%, then by achieving a protein level of between 11-12% then you will achieve the optimum yield and around $30/tonne extra as compared to ASW grade. In Australia, the bulk of wheat growers produce ASW and APW grades. By getting all loads into APW farmers can increase their revenues significantly.

## Conclusion:

Precision Agriculture is defined as the process of making incremental improvements in productivity and profitability by collected and analysing data from the fields and then applying corrective actions. It is commonly quoted that farmers have around 40 opportunities in their working lives to get it right at harvest. So every year counts.

Nitrogen fertilizer is one of the most critical nutrients that farmers can use to take corrective actions in their fields to effect yield and crop quality; however you cannot take corrective actions unless you can quantify it first. An On Combine NIR analyser is the Missing Piece of the PA Puzzle for farmers, i.e., the Protein/Nitrogen Layer. It provides a layer of information on Nitrogen Uptake and Availability that yield alone cannot provide. By combining yield and protein measurements, then farmers have a more complete solution on how to generate Variable Rate Nitrogen Fertilization prescriptions that can increase yield and reduce fertilizer costs.