Measuring nitrogen uptake and availability in the field

■ **By Phillip Clancy**

NITROGEN is one of the major nutrients in plant growth and development. And measurement of the amount of available nitrogen in the soil helps in predicting crop yield. But soil testing can be a costly and time consuming procedure. Measuring nitrogen uptake in the plants provides us with a layer of information that helps us 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 a more complete understanding of the impact of nitrogen fertilisation can be achieved across the paddock.

The following outlines 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 to develop tillers. For wheat crops, between 330 to 400 tillers per square metre should be evident.

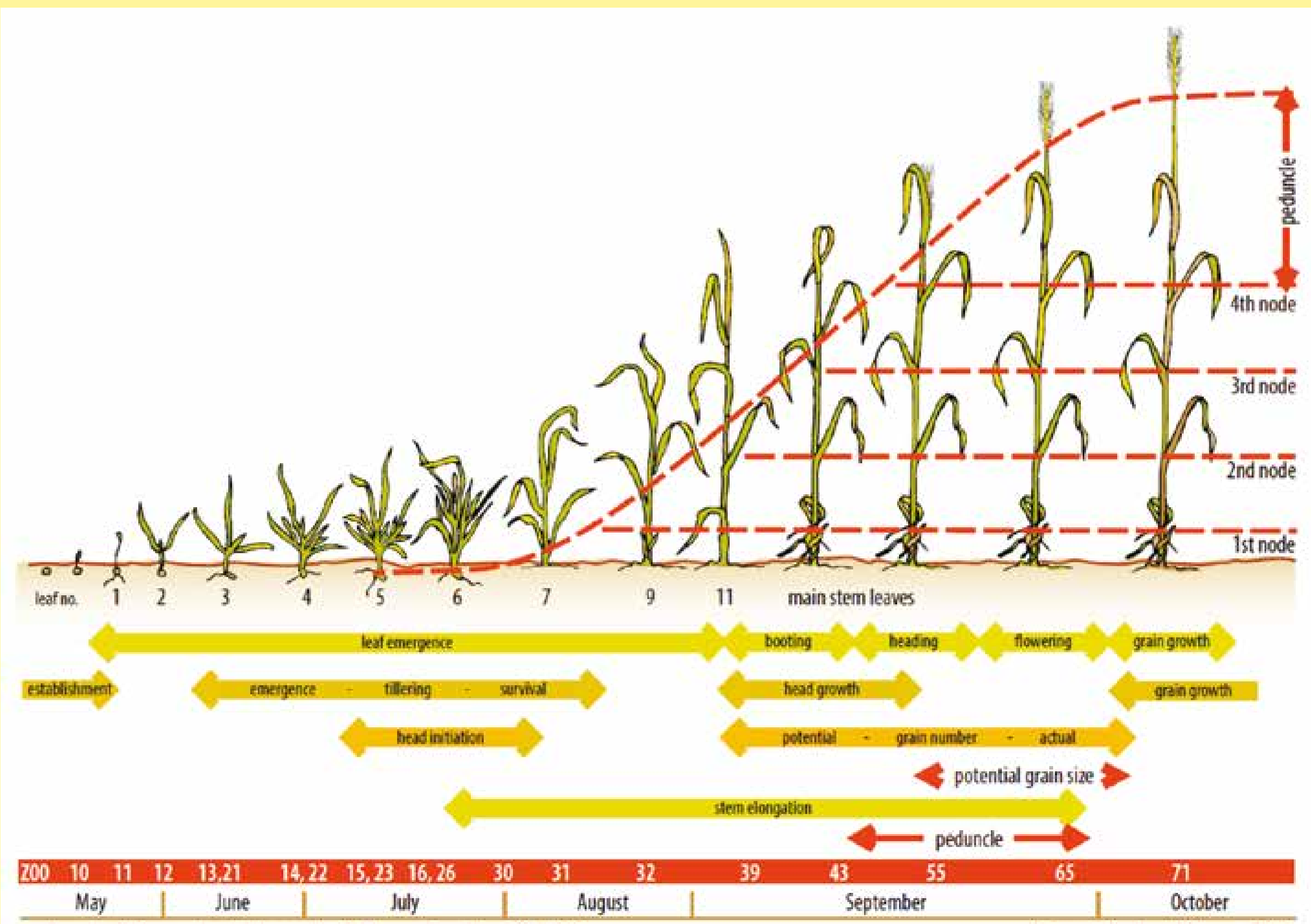
This means around 6–8 tillers per plant should be growing.

If there is not enough nitrogen present as nitrate ions in the soil at this early stage, then the crop will never achieve its water limited yield potential because there will not be enough heads produced. If there is sufficient nitrogen present then the plant should produce the 6 to 8 tillers. Figure 1 shows the growth phases for spring wheat.

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. The number of heads that can be produced by the plant has been determined – and therefore the yield potential.

You cannot recover the yield loss (due to insufficient tillers) by adding more nitrogen once the tillering phase has finished.

FIGURE 1: Wheat growth stages



* under good condition some plants will have a coleoptile tiller appearing between Z11 and Z12

Source: Based on M Stapper, 2007.

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 – that is, 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 – thereby maximising 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 maximise 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 thereby increasing 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 both yield and protein will be high.

As a general rule, applications of nitrogen from sowing to stem elongation increases yield, while applications after stem elongation increases 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. Proteins are polymer chains formed from peptides which are made up of amino acids.

When humans and animals eat and digest proteins, amino acids are released which rebuilds body tissues such as skin, muscle and organs.

Edible plants such as wheat, soybeans, corn and rice make amino acids. When these amino acids are digested in the human or animal gut, peptides are formed which then go to make proteins.

The proteins found in the seeds of a plant have approximately 16 to 18 per cent nitrogen in them. As such, for every load of grain harvested from a field there is a portion of the load that is protein and nitrogen.

For example, if the protein content of the grain is 10 per cent then 100 kg of each tonne of grain is protein. And out of this 100 kg of protein there is 16 per cent nitrogen – or 16 kg.

This means that for every tonne of 10 per cent protein grain harvested off that paddock, 16 kg 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.

Nitrogen and yield tells a more complete story

Yield maps measure the mass of grain that is harvested per hectare. Yet for the past 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 fertiliser 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 as well as during the stem elongation and flowering phases.

At this time, there is no instrument that can perform such a measurement in real-time. But an on-combine NIR analyser (such as the CropScan 3000H) is designed to measure protein, oil and moisture in grain and oilseeds as the grain is harvested.

As protein is a direct measure of the nitrogen in the seeds, then this instrument can be used to generate a nitrogen removal map. Figure 2 shows a protein map, a yield map and nitrogen removal map for a wheat field in South Australia.

The yield map shows that there are large areas where the yield is low (red areas). Based on the yield map, the conclusion would be that more nitrogen is needed in these areas.

But the protein map shows that the same areas had high protein (blue areas).

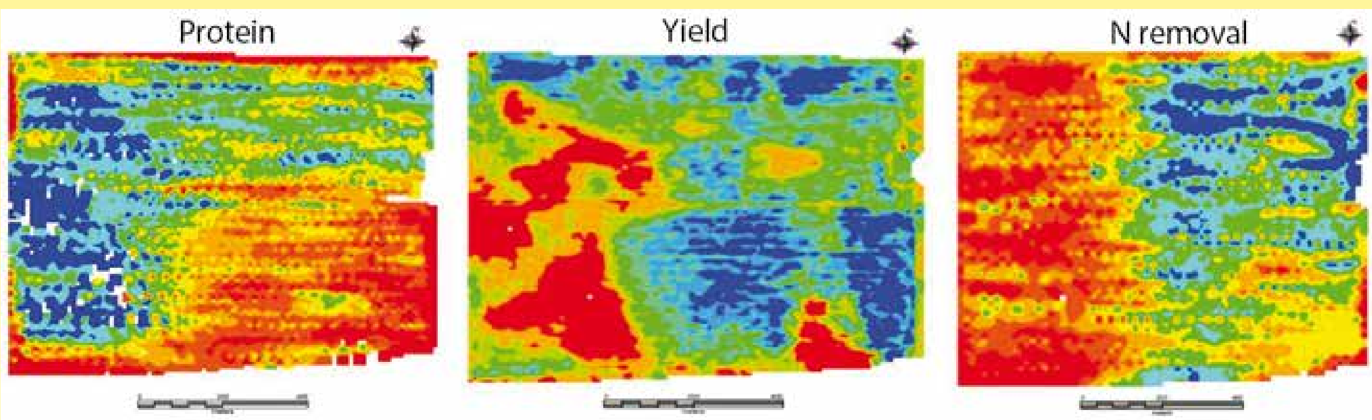
From the earlier comments above, it's apparent that there was sufficient nitrogen to fill the grain with protein.

But the yield and the protein maps appear to be contradictory. The explanation is that there was insufficient nitrogen in the soil at the time of planting and up to the end of the tillering phase.

However, the story is not finished yet.

The yield map shows a large area where the yield is high (the

FIGURE 2: Protein, yield and nitrogen removal maps from a South Australian wheat field



Grain protein, oil and moisture content can now be measured on the go.

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 per cent, making it ASW grade.

In 2015 the difference in price between ASW and APW grades was $30 per 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, rainfall history, soil types and fertiliser history are important factors in understanding what has driven the plant growth in this particular paddock. A look at the nitrogen removal map shows that there are three zones:

- Red Zone 1 – left hand side;
- Blue Zone 2 – top right hand corner; and,
- Green Zone 3 – bottom right hand corner.

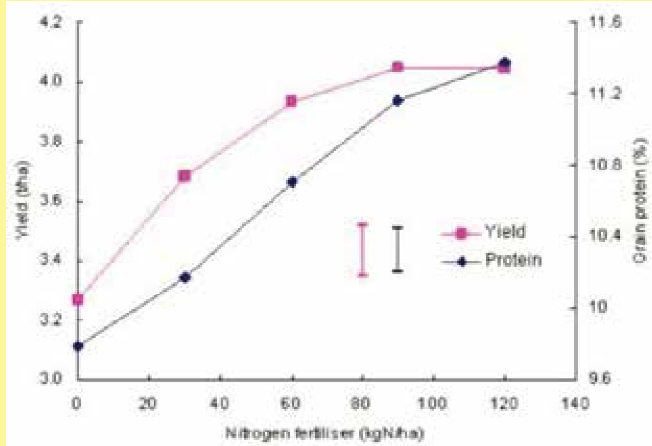
Reviewing the soil types in these three zones may lead to better timing of fertiliser application so that nitrogen is not leached from the root zones by rain shortly after planting.

Reviewing the fertiliser 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 plan a more effective fertiliser strategy for the field so that the three zones are more consistent in terms of yield and protein.

Although a reduction in the amount of nitrogen fertiliser may be possible, it is more likely that the fertiliser could be applied more effectively and result in higher yield at the optimum protein grade.

FIGURE 3: The relationship between wheat yield and protein



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. But another equally relevant 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.

Canadian (Alberta) agronomist Steve Larocque from Beyond Agronomy, stated in a recent 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 per cent protein.

If the protein is not at this level, then the crop will not have reached its full potential yield.

Figure 3 shows the relationship between yield and protein. The optimum protein level for hard wheat is between 11 and 12 per cent. If you are not growing wheat at this protein level then you are not achieving the water limited potential yield.

APW grade requires a protein above 10.5 per cent. If you can achieving a protein level of between 11 and 12 per cent then this indicates you have achieved the optimum yield while also enjoying $30 per tonne extra compared to ASW grade.

In Australia, the bulk of wheat growers produce ASW and APW grades. By getting all loads into the APW classification, farmers can increase their revenues significantly.

To sum up

'Precision Agriculture' can be defined as the process of making incremental improvements in productivity and profitability by collecting and analysing data from the fields and then applying corrective actions.

It is often said that farmers have around 40 opportunities in their cropping careers to "get it right at harvest".

So every year counts and nitrogen fertiliser is one of the most critical nutrients that farmers can use to take corrective actions in their fields to effect yield and crop quality.

But 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. It provides a layer of information on nitrogen uptake and availability that yield alone cannot provide.

Phillip Clancy is a Director of Next Instruments an Australian owned family company that has been developing innovative analysers for the food and agriculture markets since 1997. See *http://nextinstruments.net/index.php* ■