Using Plant Physiology to Diagnose Nitrogen Deficiency in Wheat

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A nitrogen nutrition index (NNI) is presented as a robust interpretation method to guide profitable and sustainable in-season N applications in dry climates with unfertile soils.

Risk management and improved confidence in diagnosing early N deficiency is the focus of this research.

Trial site in South Australia with different wheat varieties growing under a range of N treatments. Part of the trial is irrigated, while the other is rainfed to determine the effects of water deficit on the N dilution curve.

Nitrogen is a major yield and profit driver for cereal production in the Mediterranean climates of Western Australia (WA) and South Australia (SA). The yield components of plants/m^2, spikelets/plant, grain number/spikelet, and grain weight in relation to N are fairly well understood. However, N fertilizer inputs can be difficult to match to the seasonal conditions, especially when only based on pre-season soil tests. Using a plant-tissue test that is more directly related to yield components such as biomass and achievable yield (and maybe protein) responses, rather than just adequate nutrient tissue concentrations at different growth stages, may overcome some of the limitations associated with a pre-season soil test and predicted mineralized N. Such a plant test may help to guide N fertilizer applications to improve crop yields and profitability with more certainty.

Abbreviations and notes: N = nitrogen.

Nitrogen supply from mineralization of organic matter is often irregular in WA and SA because of fluctuations in soil moisture and temperature. Low and unreliable rainfall in these climates restrict N supply and target yields. It makes sense to adopt a flexible and robust strategy that can account for changes in soil and seasonal conditions and thereby reduces the risk of mis-matching N supply and demand with fertilizer N applications rates and timings. Past research has worked towards a N nutrition index (NNI) obtained from whole shoots in well-watered, high-yielding conditions. Can the same concept be transferred to water-limited and lower-yielding growing areas in WA and SA? This question is being investigated in a project led by Dr. Sadras. He recently reviewed the NNI and linked the concept to plant water relations (Sadras and Lemaire, 2014). This NNI concept, if adjusted to water-limited climates, may have the potential to provide a useful tool for growers/advisers to guide in-season N recommendations in order to close the yield gap between actual and target yields, similar to the interpretation model developed by the fertilizer company CSBP Ltd. (Southern, 1985) for macro- and micronutrients in WA.

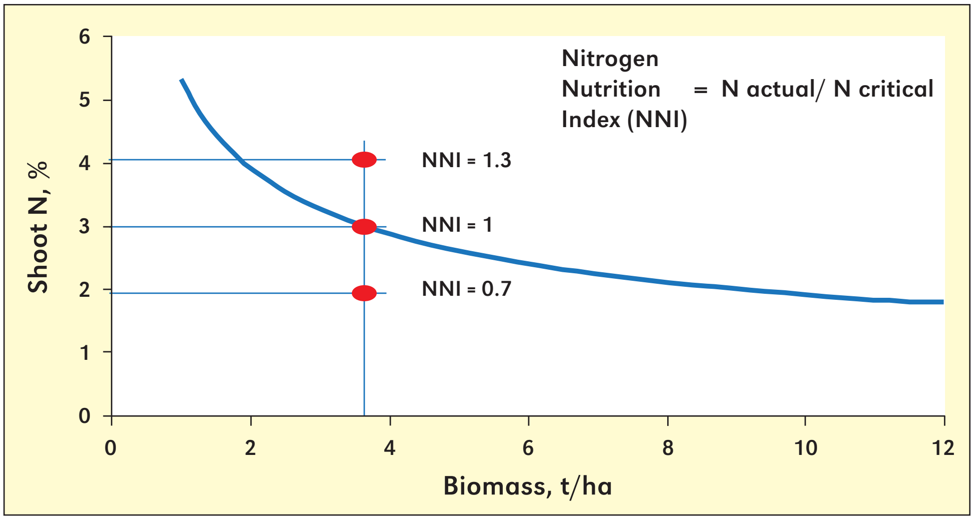

Figure 1. Example of a critical N dilution curve for the crop vegetative period in well-watered conditions. Red points represent three plant tissue tests for shoot N concentration and the corresponding biomass to illustrate when N would be deficient in the plant (NNI < 1, N concentration is below the minimum N concentration that is required for maximum growth), sufficient (NNI = 1, N concentration is matching the minimum N concentration for maximum growth) or in high, luxurious supply (NNI > 1, N concentration is above the minimum N concentration that is required for maximum growth).

Determination of NNI

A critical N concentration represents the minimum N concentration that is required to achieve maximum biomass. Crop growth is a sensitive indicator that integrates all major constraints, including water and N supply. Crop growth is also directly related to N uptake and slows down under N deficiency. Maximum growth would lead to maximum yield in well-watered conditions, but doubts can be raised for cropping areas with a hot, dry finish that reduces harvest index (Heerwaarden et al., 1998). Canopy management in these water-limited climates may favor below maximum growth, which can be controlled with N deficit. Thus this benchmark of maximum growth needs to be tested and validated before developed further for WA and SA conditions.

Over the course of a season the critical N concentration naturally decreases as the crop grows and the leaf to stem ratio declines. This is because stem or structural tissue has a lower N concentration than the photosynthetic leaf tissue. Furthermore, competition for light increases and more N is translocated within the plant from older, shaded leaves to younger, more photosynthetically active leaves. The end result of these processes over the course of the growing season is a critical "N dilution curve" that can be obtained from trial data by drawing a line through all critical N concentrations plotted against crop biomass (**Figure 1**). NNI is a calculated ratio using the measured N concentration in relation to the established N dilution curve.

The NNI is a robust concept in that plant sampling can occur throughout the vegetative period when fertilizer decisions are made. Whole shoot sampling is relatively easy and quick and is ideal for interpreting mobile nutrients that get remobilized within the plant, such as N.

This plant physiological concept needs to be calibrated using local trial data, thereby integrating variety and climate specific conditions that are reflected in the whole shoot N analysis at the time of sampling. The expectation is that dilution curves will "shift" downwards under water deficit, and with varieties storing high concentration of water soluble carbohydrates (Hoogmoed and Sadras, 2016).

More importantly, NNI can be used as an intermediate variable to correlate to yield and protein. More relevant information can be made available for N decision making on farms, assuming the N uptake would not be limited by other nutrient deficiencies, or the growth stage, and that weather conditions are favorable. The NNI to yield correlation will also show if crop yield peaks at NNI < 1, which would indicate the benefits of some degree of N deficit in WA and SA.

This NNI will be explored in greater detail in field trials conducted currently in SA and WA. The aim of these trials is to validate the plant physiological framework and to investigate the interaction of N nutrition and water deficit in rainfed broad-acre agriculture. BC

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