Closing the Yield Gap for Wheat and Canola through an Adjusted Nitrogen Nutrition Index

By Andreas Neuhaus, Marianne Hoogmoed, and Victor Sadras

A new wheat and canola nitrogen nutrition index (NNI) has been developed as an interpretation method for more profitable and sustainable in-season N applications in dry climates with unfertile soils.

Crop advisers and growers can use the N Nutrition Index (NNI) to improve risk management or certainty around in-season N applications in wheat and canola. Once shoot N concentration and shoot biomass are measured or estimated using relevant tools in the field, a NNI can be calculated.

The theoretical concept of a NNI was introduced in a previous issue of *Better Crops* (Neuhaus et al., 2016). In brief, the NNI is a measure of crop N status. It is calculated as the ratio of actual N concentration (as measured in the crop) to critical N concentration. Critical N concentration is the minimum concentration of N that a crop requires to achieve maximum growth and can be determined experimentally. This concentration reduces with biomass growth, and this is captured in a so-called N dilution curve, which related critical N concentration with biomass. It was argued by Justes et al. (1994) that maximum crop growth would lead to reaching full yield potential, hence a NNI ≥ 1 is desirable.

This approach uses crop growth as a relatively easy-to-obtain, sensitive, and flexible indicator for benchmarking N deficiency throughout all crop stages (without the need of a skilled agronomist to identify crop stages correctly). However, doubts remained whether maximum crop growth would also lead to maximum yield in water-limiting environments. This article provides an update on NNI research through a comparison of wheat and canola, and proposes an adjustment which accounts for the water x N interaction.

Wheat and canola are two major crops grown in western and south eastern Australia. Nitrogen dilution curves required to calculate NNI for these crops have been determined in temperate climates with high yield potentials (Ulrich, 1952; Greenwood et al., 1990; Justes et al., 1994; Lemaire et al., 2008; Colnenne et al., 1998). By transferring the concept and applying the same equations for NNI to wheat and canola in the climate of Western Australia (WA) we observed an over-estimation of N deficiency (**Figure 1**). Hence there is a need to adjust the critical N dilution curves for water-limiting environments.

Abbreviations and notes: N = nitrogen; NNI = nitrogen nutrition index.

In order to transfer the NNI concept to water-limited and lower-yielding growing areas in WA we investigated the impact of rainfall and also addressed the often-seen N deficiency at early plant stages (shoot biomass < 1 t/ha in wheat and < 1.4 t/ha in canola) where the fraction of nitrates in wheat are considered to be an equally important indicator of N status apart from total N (%). NNI and plant water relations are linked (Sadras and Lemaire, 2014) and hence a lower N dilution curve under certain rainfall conditions may provide better correlations with yield data.

We found that by applying the methodology of Greenwood et al. (1990) on our dataset to derive a new N dilution curve ($3.91 \times \text{biomass}^{-0.32}$) for winter wheat and then adjusting the NNI to rainfall (and nitrates for wheat < 1 t/ha biomass), we obtained a better NNI-yield correlation (**Figure 2**). For canola, the N dilution curve by Colnenne et al. (1998) was adequate for annual rainfall over 400mm, but was adjusted by a factor 0.5 for crops grown with less than 400mm of annual rainfall.

Interestingly, when comparing both crops in the same graph and plotting NNI versus absolute yield (**Figure 3**), the pattern of the yield ratio between the two crops (i.e., canola:wheat = 0.5) and the slope towards maximum yield (i.e., 2.85:5.7 = 0.5) are matching.

The calibrated, local trial data above integrates different

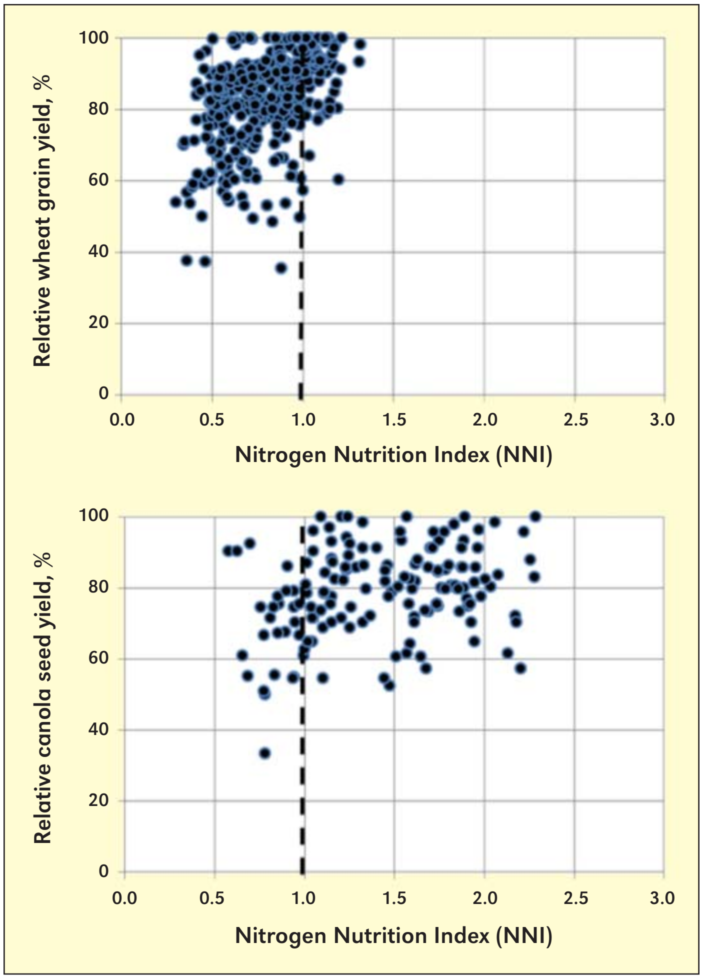

Figure 1. Application of the NNI from high-yielding, temperate climates shows sufficient N for wheat growth in particular, even if the NNI is < 1.0, which theoretically should indicate N deficiency and yield responsiveness to N applications. Graphs for wheat (top) and canola (bottom) were produced using CSBP Ltd. research trial data from WA. To calculate NNI, the critical N dilution curve for wheat with biomass > 1 t/ha (N = 5.3 x biomass^ - 0.44) was taken from Justes et al. (1994) and the curve for canola with biomass > 1.4 t/ha (N = 4.48 x biomass^ - 0.25) was taken from Colnenne et al. (1998).

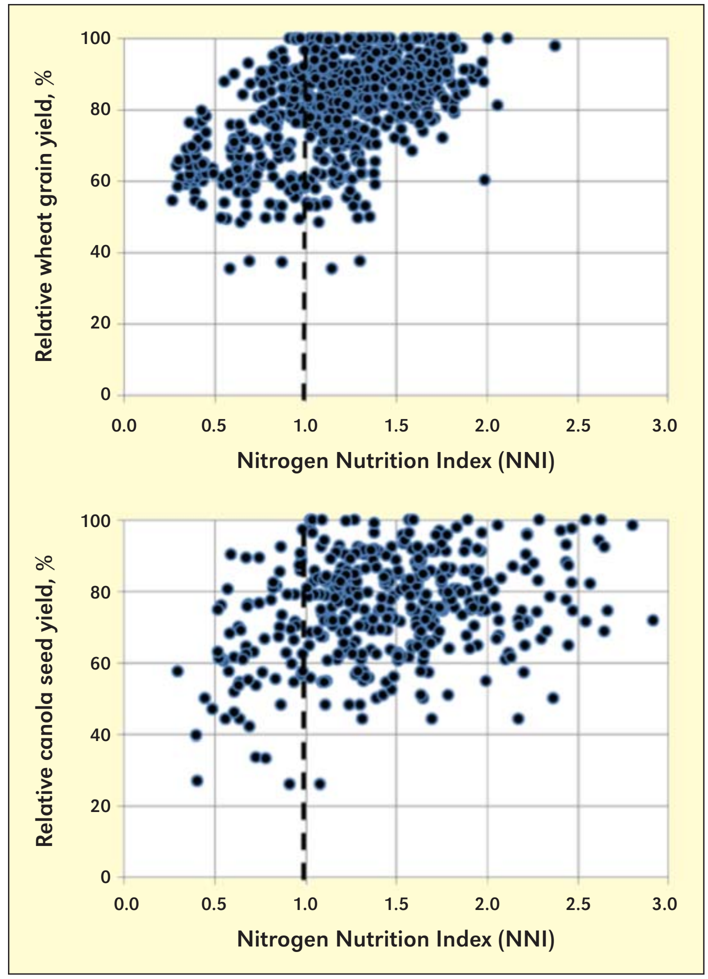

Figure 2. Adjusting the NNI by lowering the N dilution curve depending on rainfall (and nitrates in case of young wheat plants) shows N deficiencies in wheat (top) and canola (bottom) when the NNI < 1.0.

TAKE IT TO THE FIELD

A NNI ≥ 1 likely means little yield response to an in-season N fertilizer application, but a later plant sampling might be considered in order to use the NNI as a monitoring tool for whenever in-season N applications are planned.

NNI EQUATIONS USED IN FIGURE 2

WHEAT (top graph)

NNI (SR† + GSR > 400mm and Biomass < 1 t/ha) = $[(\%\ N / (3.91 \times \text{biomass}^{-0.32})) + (\text{mg/kg } NO_3 / (610 \times \text{biomass}^{-0.91})) / 2]$

NNI (Biomass > 1 t/ha) = $\%\ N / (3.91 \times \text{biomass}^{-0.32})$

NNI (SR + GSR < 400mm) = $\%\ N / [(3.91 \times \text{biomass}^{-0.32}) \times 0.7]$

CANOLA (bottom graph)

NNI (SR + GSR > 400mm and Biomass > 0.88 t/ha) = $\%\ N / (4.48 \times \text{biomass}^{-0.25})$

NNI (SR + GSR < 400mm) = $\%\ N / [(4.48 \times \text{biomass}^{-0.25}) \times 0.5]$

†SR = Summer Rain; GSR = Growing Season Rain.

varieties, management, soil, and climate-specific conditions. The initial hypothesis that dilution curves from high-yielding environments will "shift" downwards under conditions of water deficit can be confirmed with this WA-CSBP Ltd. dataset. The research on NNI is ongoing and alternative approaches using growth stage instead of biomass to relate to critical N concentrations will be be explored.

Summary

This research can applied by crop advisors to offer improved risk management or certainty around in-season N applications. Once shoot N concentration and shoot biomass are measured from field samples or estimated using relevant tools in the field, a NNI can be calculated. Thereafter, fertilizer decisions could be based on closing the yield gap between

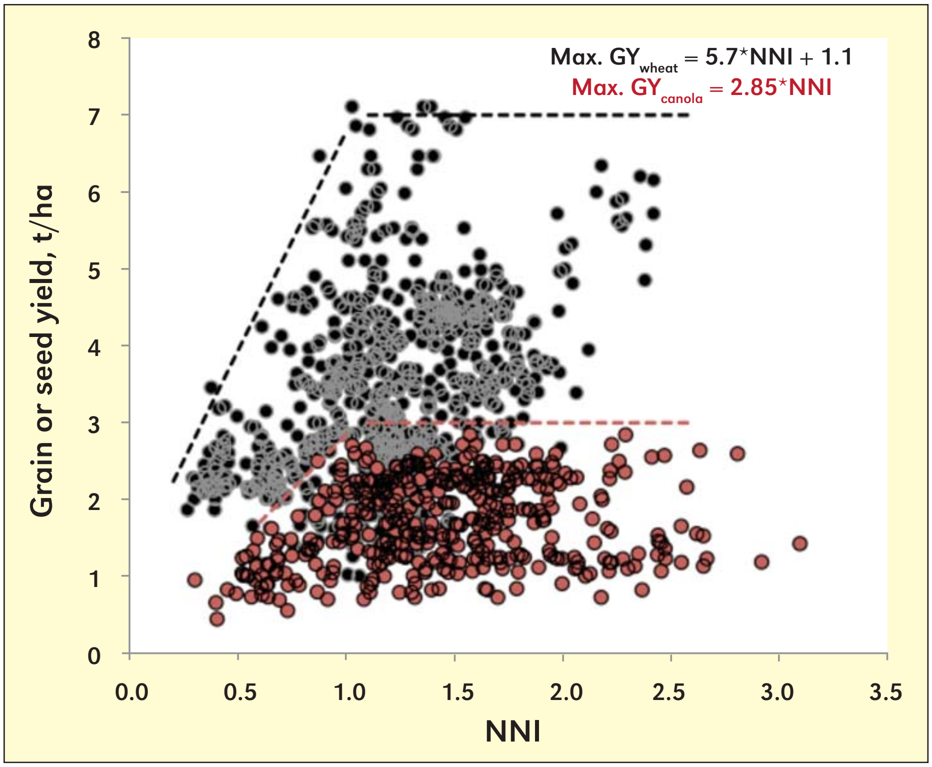

Figure 3. A rainfall-adjusted NNI < 1.0 corresponds to decreasing yield in wheat and canola.

yield potential at the calculated NNI and the water-limited yield potential that could be achieved in that season depending on rainfall. BC

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Dr. Heidi Peterson Named IPNI Phosphorus Program Director

Dr. Heidi M. Peterson has been hired as Phosphorus Program Director with the International Plant Nutrition Institute (IPNI) effective September 5, 2017. Dr. Peterson is filling the directorship previously held by Dr. Tom Bruulsema, who was appointed as IPNI Vice President, Americas and Research, earlier this year.

"Dr. Peterson comes to IPNI with significant leadership, teaching, and research experience surrounding phosphorus stewardship issues," said Dr. Terry Roberts, IPNI President. "We look forward to the impacts Heidi will have on the Institute's research and educational missions," Roberts added.

Dr. Peterson completed her Ph.D. in Biosystems and Agricultural Engineering (2011) at the University of Minnesota in St. Paul. Her Dissertation was titled "Estimating Renewable Water Flux from Landscape Features." She has a M.Sc. in Agronomy (2003) from Purdue University in West Lafayette, Indiana. She completed her B.Sc. (2000) in Natural Resources and Environmental Science, at Purdue University.

Most recently and since 2013, Dr. Peterson worked as a Research Scientist for the Minnesota Department of Agriculture. She was the lead technical expert on agricultural best management practices (BMPs) needed to address impaired waters issues within the state's agricultural landscapes. The position gave her oversight over research focusing on cover crop establishment and nutrient crediting, precision conservation, nutrient management, and innovative sub-surface drainage treatment.

Dr. Peterson has also been actively collaborating (since 2013) with phosphorus research scientists participating within tasked working groups of the Phosphorus Sustainability Research Coordination Network (P RCN), centered at Arizona State University. Dr. Peterson has been Adjunct Assistant Professor for the Department of Bioproducts & Biosystems Engineering at the University of Minnesota (U of M) since 2014. Previous to these positions, Heidi worked as a Post-Doctoral Research Fellow with the U of M Department of Bioproducts & Biosystems Engineering.

Dr. Heidi Peterson
IPNI Phosphorus
Program Director

Heidi belongs to the American Society of Agronomy, American Society of Agricultural and Biological Engineers, the Soil and Water Conservation Society, and the International Network of Research on Coupled Human and Natural Systems. She will be based in Stillwater, Minnesota, U.S.A.