FINAL REPORT

DAS00147

Benchmarking wheat yield against nitrogen use

PROJECT DETAILS

PROJECT CODE:	DAS00147
PROJECT TITLE:	BENCHMARKING WHEAT YIELD AGAINST NITROGEN USE
START DATE:	01.07.2014
END DATE:	30.06.2017
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Summary

Nitrogen management is an economically important decision for farmers. This project

1. developed a new benchmark for wheat N-status,
2. showed that commercial crops in a rainfall transect in South Australia were largely well fertilised (no deficit or excess);
3. indicated 2 out of 5 National Variety Trials (NVT) were underfertilised, where N-status might bias the ranking of varieties.
4. Using the N benchmark, we identified causes of yield gaps: mostly rainfall in SA, and low sowing rate in lower rainfall areas of Western Australia .
5. Found that selection for yield over five decades has dramatically reduced the root biomass and root length density of wheat, and increased N uptake per unit root length.

Conclusions

Finding 1: "Water-soluble carbohydrates affect critical nitrogen concentration in wheat."
Breeding for yield has increased the concentration of water-soluble carbohydrates (WSC) in wheat. This increase in WSC can reduce the concentration of nitrogen (N) in shoots and consequently reduce the crop critical N concentration. This may cause errors when assessing a crop's N status using dilution curves which relate critical N concentration and shoot biomass. In this project we

1. outlined the drivers of variation in WSC,
2. analyse the implications of WSC on wheat N status,
3. propose an adjustment of the theoretical N dilution framework that makes explicit a WSC compartment, and
4. provide estimates of the range of error derived from the current model overlooking WSC.

Finding 2: "Nitrogen dilution curves of wheat are less robust than usually assumed."
Nitrogen dilution curves relate a crop's critical N concentration (%Nc) to biomass (W). This model has a strong theoretical foundation, and parameters of dilution curves show little variation for well-watered crops. In this project we explored the robustness of this model for water stressed crops. We compared models where %Nc was plotted against biomass, growth stage and thermal time. The three models were similarly scattered but the scatter was better explained in the biomass model, particularly by water availability. We concluded that the biomass dilution model developed for well-watered crops overestimates nitrogen deficiency of water-stressed crops, and a biomass-based model is conceptually more justified than developmental models. For practical diagnostics, locally-estimated %Nc for particular growth stages could be useful.

Finding 3: "A new benchmarking tool for wheat yield against crop nitrogen status."
Availability of N and water are major constraints for crop yield, and their interactions are manyfold. Yield gap analysis in rainfed systems commonly uses the French and Schultz water-limited yield potential as a benchmark. Benchmarking against nitrogen-limited yield potential (YN) is uncommon; this project aimed at filling this gap. Experiments were established under a range of water availability and wide ranges of soils and management practices, including varieties, sowing dates, sowing rates and fertilisers. We measured wheat actual yield, quantified crop nitrogen nutrition index (NNI) at stem elongation, anthesis or both, derived boundary functions relating YN and NNI, calculated yield gaps as the difference between YN and actual yield, and explored the associations between yield gaps and environmental, crop and agronomic factors. To quantify NNI we used the locally determined critical N concentration described under finding 2. Maximum attainable yield (7.8 t/ha in South Australia , 6.5 t/ha in Western Australia) was found for NNI higher than 0.95 in SA, 0.87 in WA (i.e. thresholds for N sufficiency).

In SA, water supply (rainfall plus irrigation) explained 54% of the yield gap. In WA the direct association between yield gap and rainfall was weak, but there was an indirect agronomic link, where low sowing rate in low rainfall environments contributed to slow growth early in the season, which in turn explained a large part of the yield gap.

NNI and yield gaps were variety-dependent. In samples from National Variety Trials (NVT), where the aim is to compare yield of current and emerging varieties, this may be a source of bias as some varieties were above or below the NN threshold of N sufficiency.

Outcomes

Economic benefits
This project has delivered (i) an improved tool for N diagnosis of crops, and (ii) a primary list of causes of N limited yield gaps. This knowledge can be used to improve N management, resulting in either lower input costs, increased yield or both. Working with CSBP's Dr Andreas Neuhaus, the project is influencing fertiliser recommendations in approx. 3,000 paddocks per year.).

Environmental benefits
The improved N diagnositcs tool and yield benchmark can be used to improve the matching of fertiliser supply and crop nitrogen demand. This can reduces the likelihood of undesirable nitrogen losses including runoff nitrogen, leaching and volatilisation, as well as prevent soil mining associated with under-fertilisation.

Social benefits:
Improved methods to quantify crop N status and determine yield gaps can give farmers more confidence in their descision making.Other social benefits are indirectly related to the environmental and economic benefits outlined above.

Output 1

Published benchmarks of wheat yield against nitrogen under rainfed and irrigatied conditions in South Australia for four current wheat varieties.

Output 2

Benchmark the nitrogen status of wheat in growers' fields and determine the size of yield gaps and measure nitrogen status of crops as affected by sowing date, fertilisation and variety.

Output 3

Data quantifying the nitrogen status of 15 wheat varieties at 2 National Variety Trials (NVT) sites (Palmer, Paskeville)

Achievement/Benefit

Australian growers routinely use the French and Schultz benchmark to measure yield gaps in relation to water use. Despite the importance of nitrogen for crop yield and its incidence in the variable costs of farm business, there is no equivalent benchmark to assess the maximum yield attainable in relation to crop nitrogen status. We do not know therefore, if cropping systems are getting the maximum benefit for their investment in nitrogen fertiliser. Likewise, it is unknown if the nitrogen input in NVT is adequate, excessive or limiting. Nitrogen management needs to be updated to achieve three important goals:
(1) capture the yield potential and grain protein concentration of new varieties, hence improving farm profit;
(2) capture the improved physiology of new varieties in NVT, hence reducing the likelihood of biased variety rankings;
(3) avoid severe soil mining associated with under-fertilisation of new varieties with high nitrogen requirements.

The scientific background of this project is the standard to quantify crop nitrogen status based on (a) a critical nitrogen concentration %Nc, which is the minimum N concentration required to achieve maximum growth, and (b) the nitrogen nutrition index NNI (a measure of crop nitrogen status), calculated as the ratio of actual and critical nitrogen. NNI = 1 indicates sufficiency, NNI $<$ 1 indicates deficit, and NNI $>$ 1 indicates excess. This concept originates in Europe in the 1990s, and uses critical nitrogen from well-watered crops. The assumption was that %Nc was stable, and original parameters have been extrapolated widely, including into crop simulation models and diagnostic tools. This project challenged this notion, and found that %Nc is lower under water deficit. Adjustments were developed to account for water deficit and other sources of variation including Australian varieties with different phenology and water soluble carbohydrates, both influencing %Nc. The adjusted %Nc value were used to quantify crop nitrogen status in experiments designed to generate a range of crop N status and yield. We benchmarked yield and protein against crop N status to determine yield gaps and identify some causes.

Communication and delivery
The project developed a comprehensive program of communication and delivery to raise industry awareness on the advanced scientific concepts underlying (i) robust diagnostic of crop nitrogen status and (ii) benchmarking crop yield and protein against nitrogen benchmarks. We primarily targeted decision makers in the industry, including growers, advisors and suppliers. Over three years, the project delivered 12 presentations to industry (field days, GRDC update, articles), 7 papers in conferences, and 6 scientific publications.

Industry and scientific impact
The largest industry impact of the project has been through the link with CSBP's Dr Andreas Neuhaus. Annually, CSBP feeds about 10,000 plant tissue tests through their "NUlogic" diagnostic system per year. Of these, 70% are for wheat and 30% for other crops including canola, barley, and pastures. The bottom line for wheat is 3 000 paddocks per year to receive a nutrient recommendation. "NUlogic" shares a conceptual base with critical nitrogen, and through this project adjustments have been made for parameters to account for water deficit, using a threshold of 400 mm seasonal rainfall. Comparison of NNI and NUlogic have reinforced the confidence on these diagnostic tools.

In a small NVT sample, 2 out of 5 trials were nitrogen deficient: Wolseley 2014 and Pinnaroo 2016. Management of nitrogen in NVT needs attention, as some varieties were above and others below the threshold of nitrogen sufficiency, hence the potential for nitrogen to be a source of bias in the rating of varieties.

The scientific impact of this work has been three-fold. First, the notion that critical nitrogen concentration is constant has been challenged, and new values of critical nitrogen accounting for water deficit and local varieties have been produced. Second, a new protocol to benchmark crop yield and grain protein has been developed and applied to crops in South Australia and Western Australia , based on the new critical nitrogen and derived nitrogen nutrition index (NNI). Third, genetic variation in agronomically-adapted wheat varieties was found for nitrogen uptake; a new double haploid mapping population has been created to use as a platform for pre-breeding work leading to markers for improved nitrogen use efficiency.

Confidentiality (Deprecated - Use IP Summary instead)

NA

Collaboration Organisations

Taise Kunrath, Gilles Lemaire and Francois Gastal (INRA France).

Collaboration Details

Investigated water-nitrogen interactions in grasses and lucerne.

References

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