FINAL REPORT

DAS00157

Nitrogen and water interactions

PROJECT DETAILS

PROJECT CODE:	DAS00157
PROJECT TITLE:	NITROGEN AND WATER INTERACTIONS
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Summary

Australian growers are aware of the need to match supply of nitrogen (N) to water availability. This involves water-N interactions that are the focus of this project. This study had two chapters. Chapter 1 reviewed the scientific and unpublished literature to provide physiological, agronomic, economic, breeding and modelling perspectives on the interactions between water and N. Chapter 2 used soil, climate and economic information to produce gross margin (GM)-risk curves, and to assess water use efficiency (WUE), N use efficiency (NUE), and total factor productivity in 11 locations representing soils and climates from the northern, southern and western regions.

Report Disclaimer

Conclusions

Where crop N is in short supply relative to the availability of water, a yield gap emerges often associated to a reduction in profit. Conversely, where N supply exceeds the requirement to achieve the water-limited yield, the return in N investment will be small or even negative. Therefore, matching N availability to water supply is critical in rainfed cropping. This study reviewed N-water interactions from physiological, agronomic, economic, breeding and modelling angles (Chapter 1).

The main insight from crop physiology is that N fertiliser drives a trade-off between efficiency in the use of water and efficiency in the use of N. It is impossible to maximise both at the same time. When growers make a decision on the rate of fertiliser, they will be indirectly selecting for solutions to this trade-off that account for the particulars of the growers' environment, financial standing and risk attitude. A major insight from a breeding perspective is that changes in N traits in response to selection for yield of wheat in dry, low N Australian environments are more widespread and more profound than changes in water related traits - better N uptake seems a critical trait for drought adaptation. This modelling study, spanning 11 locations from northern, southern and western regions, showed that GM-risk curves can be shifted favourably using soil (N, water) and forecast information (Chapter 2). The gains to be made from this approach depend on soil and climate, and need to be tested experimentally.

Recommendations

One of the key aims of this scoping study was to produce recommendations for future investment on research and development (R&D) in the area of water-N interactions. This is important, because much research has looked at water or N separately. Significant gains are to be made by research, development and extension (R,D&E), where a double focus on water and N is applied. A review of the literature identified gaps that led to 12 recommendations for future work on agronomy, breeding, physiology and modelling. The full justification for these recommendations is in the Attachment to this report.

Outcomes

The project combined a literature review and modelling to create new information. The outcome of this scoping study is a list of 12 recommendations for further R,D&E that will guide future industry investments on agronomic and breeding solutions to improve the exploitation of water-N interactions.

Achievement/Benefit

In Chapter 1, the interactions between the water and N economies of crops from complementary physiological, agronomic, economic, breeding and modelling perspectives were reviewed. The primary focus was wheat, the main crop in Australia. Other species were also discussed for comparison, including forage crops where advanced notions on the physiology of water and N have been proposed, sorghum where current understanding of stay-green illuminates some of the connections between N and water, and pulses, where intra-specific variation in N fixation under drought seems relevant for crop yields. A data set of 274 wheat crops was compiled that spans the range of soil, climates and management in Australia. Frequency distributions and quantile regressions were used in the analysis. Median wheat yield was 2.7t/ha and median grain N concentration 1.7% where fertilisation was below 25kg N/ha in comparison to median yield of 5.3t/ha and median grain N concentration 2.1% for their counterparts with more than 151kg N/ha. Yield and biomass responses to fertiliser were 2-3 larger under favourable conditions (90th percentile) than under stress (10th percentile). Grain N concentration correlated with N fertiliser rate under favourable conditions, but not under conditions conducive to low grain protein. Variation in yield was mostly related to variation in biomass, whereas median harvest index was relatively stable, ranging from 0.38 with less than 25kg N/ha to 0.41kg at 151kg N/ha or more. The relationship between harvest index and fertiliser had slopes indistinguishable from zero for both 90th and 10th percentiles.

Comparison of N export in grain and the input of N fertiliser across these environments indicate a cutting point for fertiliser of approx. 50kg N/ha - below this rate, export exceeds input suggesting likely soil mining. This coarse estimate of partial nutrient balance is consistent with a detailed, long term experiment at a single site in Victoria (VIC) where the ratio between N removed and applied was 1 for rates of fertilisation between 40kg and 80kg N/ha.

In Chapter 2, expert regional crop management and soils knowledge were used to parameterise the Agricultural Production Systems sIMulator(APSIM) model and simulate the value of six strategies to inform N fertilisation practices. Nitrogen management practices were decided based on information of (i) soil water at sowing; (ii) soil N at sowing; (iii) both water and N at sowing; (iv) a seasonal rainfall forecast (Predictive Ocean Atmosphere Model for Australia (POAMA)), and two controls; (v) a control where fertiliser decisions were the same every year, i.e. ignoring soil or climate information; and (vi) a control called perfect knowledge, when the decision of N fertilisation was based on actual rainfall. Eleven sites across northern, southern and western Australia were selected to capture different climates and soils: Dalby, Emerald, Goondiwindi, Minnipa, Yorketown, Merredin, Moora, Wogan Hills, Condobolin, Wagga Wagga and Birchip. The experiment included the six management strategies and rates of N from zero to 250kg N/ha, in 10kg N/ha increments. APSIM was then used to simulate yields, water and N use, water stress index and N stress index. Efficiency measures were also calculated, including WUE (yield per unit of evapotranspiration), total factor productivity ((TFP), yield per unit of fertiliser), gross margin (GM) and financial risk. Two measures of risk were used - the chance of a negative gross margin, and a return on investment (ROI) lower than 1.10. The profit-risk curves varied with fertilisation strategy. The value of soil information and POAMA to support N management differed greatly across Australia's grains regions, and across levels of investment in N fertilisers. However, in rainfed cropping, yield and consequently growers' profits, depend not only on the N nutrition of the crop, but also on the capacity of growers to match genotype and management to the growing environment and expected seasonal conditions. Thus, the full potential from using soil and POAMA information can only emerge from fully integrating this information with information about crop variety (e.g. maturity group, tillering pattern, lodging, disease tolerance), soil (depth, available water), management and climate (sowing window against frost and heat risk).

The study concluded with 12 recommendations for future investments in R,D&E:

1. Yield-soil N relations are highly scattered because other factors such as water constrained crop responses to nutrients. Plant-based diagnostic tools remove some of this noise. Thus, it is proposed to develop N dilution curves for major crops accounting for the effects of water deficit, and explicitly including a compartment of water soluble carbohydrates. These dilution curves will allow for unequivocal assessment of the N status of crops, which are in turn necessary for calibration of tools for both diagnostic purposes in crop management, and high-throughput methods in breeding.

2. Fertiliser recommendations are generic, but there is an increasing interest in variety-specific differences in response to N. Thus, it is proposed that (a) the N demand and responsiveness to fertiliser, in terms of yield and protein, of new wheat and barley varieties are assessed, and (b) the benefits of tailoring fertiliser management to specific varieties are explored.

3. The French & Schultz model has been instrumental in crop management for rainfed systems in Australia. By analogy to the

yield-evapotranspiration relationship, it is proposed that the N uptake vs evapotranspiration relationship is investigated, particularly its association with grain protein, the N:water ratio required to close the yield gap and its potential applications in crop management.

4. Growers are familiar with the concept of bucket size for water, but there is no equivalent for N. It is proposed that the concept of plant available N and field methods to measure it are expanded. Practical aspects of soil sampling need some attention, e.g. spatial variation, transport from the farm to the laboratory, and timeliness of laboratory results to support decisions.

5. There is large variation in the impact of N supply on water uptake, thus the need to establish the combination of crops, soils and growing conditions where additional N can contribute further soil water uptake. This is more likely to be relevant in the northern region, where stored soil water (SSW) is important.

6. Some components of cropping systems (pasture, green manure) contribute N, but may reduce water available to subsequent crops. The trade-offs between N supply and water consumption by pastures and green manures in different combinations of soil, climate and rotations in both winter and summer rainfall regions need to be quantified.

7. Risk analysis of fertiliser decisions generally assumes that all the benefit of N application is constrained to a single season. Given emerging experimental evidence, there is a need to (a) determine the size of the carryover effect for different combinations of crop, soil, climate and management, and (b) update risk analysis to account for carryover of N beyond the application season.

8. Comparison of old and new varieties has been useful in identifying the increasing demand of N in new wheat varieties. Following on from this work, it is of interest to: (a) Determine the physiological and genetic basis of N uptake in old and new wheat varieties with a proven difference in N uptake in winter-rainfall field conditions, and (b) compare water and N related traits in historic sets of wheat varieties agronomically adapted to grow on SSW, e.g. the summer-rainfall environments of northern Australia. The environments where rainfall transitions from summer to winter-dominant can also be of interest.

9. Superior soybean lines have been selected for maintenance of N fixation under drought. Research in temperate legumes lags behind soybeans and other sub-tropical species. Hence, there is a need to screen temperate pulses for N fixation in soil dry-down experiments, and establish the adaptive value (in terms of yield) of this trait.

10. Sorghum is the more important summer cereal in Australia and is supported by local breeding, whereas growers rely on putatively less adapted maize hybrids developed overseas. It is proposed that (a) sorghum and maize are compared to understand the differences in phenotypes (e.g. tillering, stomatal sensitivity, response to sowing density) between breeding programs in USA (maize) and Australia (sorghum) and (b) the profitability and risk of different genotype x environment x management (G x E x M) combinations for sorghum and maize (hybrids, plant density, row configuration, sowing time, soil type and N fertilisation are determined).

11. Modelling studies are a cost effective approach to generate agronomically interesting information across regions and climates. It is proposed that the nationwide, probabilistic patterns of supply and demand of water and N for major crops as background for agronomic, e.g. timing of fertilisation, and breeding studies, e.g. root patterns are modelled and mapped. Associated with this proposition, there are species-specific gaps, as well as gaps related to basic physiology and modelling. Nationwide patterns of water stress have been produced for wheat, maize, sorghum, field peas and chickpeas. Remaining crops to be modelled are canola, lentils, lupins and faba beans. Associated with these, the quantification of the critical period of canola, lentils and faba beans needs attention. The patterns of demand and supply for N need to be developed for all crops. To support this, improved models of N mineralisation accounting from variation in soil and crop residues, and better understanding of genotype-dependent root N uptake are needed.

12. To test and capture the value of soil information (initial water and N) and POAMA forecasts, there is a need to (i) establish a network of farm case studies representing the northern, southern and western regions, (ii) compile and integrate soil, genotype, climate and management information, (iii) engage with growers to discuss these strategies in relation to relevant and actionable decisions, (iv) use APSIM to test the value of initial soil conditions and POAMA, (v) compare APSIM results with real-farm outcomes, and (vi) formalise location specific recommendations on the relative value of different sources of information.

Collaboration Organisations

Peter Barraclough (UK), Rosella Motzo and Francisco Giunta (Italy) provided original data from their experiments. These data were used in Chapter 1, to analyse changes in N traits in historic series of wheat breeding.

Collaboration Details

Collaborators facilitated data sets of wheat experiments.

Additional Information

Publication

Sadras, V. O., Hayman, P. T., Rodriguez, D., Monjardino, M., Bielich, M., Unkovich, M., Mudge, B. and Wang, E. (2016) Interactions between the water and nitrogen economies of crops: physiological, agronomic, economic, breeding and modelling perspectives. Crop and Pasture Science, 67 10: 1019-1053.

Attachment

Full report - Interactions between the water and nitrogen economies of crops.