Wheat yield targets, and water and nitrogen use efficiency in northern New South Wales

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Summary. Knowledge of the efficiency of water and nitrogen use for wheat grain production can be used with that of soil nitrate-N and soil water at planting, and in-crop rainfall expectation to determine yield targets and crop nitrogen need under commercial conditions. Water use efficiency for grain production will be reduced by nitrogen deficiency, and nitrogen use efficiency reduced by inadequate water availability. These concepts are being evaluated in northern NSW, and are discussed in this paper.

Introduction

A decline in soil nitrogen fertility with continuous cereal cultivation was first reported in northern NSW 40 years ago (5), but ceased to cause concern as wheat growing expanded rapidly in the most northerly shires after the late 1960's. However, by the mid-I980's, responses to N fertiliser were widespread (3) and much of the variation in commercial wheat grain yield could be explained by available soil water and nitrate-N at planting (6).

Grain growers need to manage soil nitrogen fertility by optimising the use of fertiliser and legume N. A combination of soil N deficiency and highly variable rainfall makes this difficult. One approach is to use computer-based decision support packages like "Wheatman" (1 I) in Queensland, which uses results of one-season fertiliser trials, climatic data, and wheat yields derived from a model. We are interested in assessing another method used successfully in the United States (I) in which N demand of wheat is estimated from potential yield which depends on the water available to the crop. Yield targets can be derived from predictions of potential yield based on water use efficiency for grain yield (WUEe: kg grain/ha/mm evapotranspiration). Estimates of WUEg for wheat in field experiments throughout Australia vary widely from 4 to 19 kg/ha/mm (4), but we are interested not in averages, but in values which can realistically predict potential yields. Values of 12.7 in South Australia (4), 12.4 in Western Australia (2), and 12.7 in northern NSW (7) might satisfy the latter condition.

The amount of nitrogen harvested can be determined for any grain yield and protein content target. Also, the quantity of nitrate-N in the soil prior to planting may be a good, single index of soil N supply in wheat-fallow systems. We propose that the N requirement of wheat can be assessed using a relationship between grain nitrogen yield (GNY) and soil N (nitrate-N: kgN/ha/ I.2m). This relationship should be near-linear in its early, N limited phase before reaching an asymptote when other factors such as water, sowing time or disease become limiting; N use efficiency (NUEg) is the linear slope. The difference between soil nitrate-N and the N needed for asymptote GNY can provide an estimate of extra N required as fertiliser for the target yield. Its usefulness will be set by the :

- reproducibility of the relationship between GNY and soil nitrate-N, or NUEg.
- predictability of a grain yield target from WUE_g when soil N is non-limiting.

In this paper, selected data from 'tillage x rotation' experiments in northern NSW, and related experiments in southern Queensland are used to examine these relationships.

Methods

Similar experiments were done at North Star, in northern NSW, on the properties `Windridge' and `Glenhoma'. The experiment at Windridge was commenced in 1989 on a degraded, red brigalow clay capable of mineralising only 40 kg/ha of nitrate-N to 1.2 m depth after short fallow in a wheat to wheat system; Glenhoma was commenced in 1990 on a grey brigalow clay, and mineralised 60 to 90 kg/ha of nitrate-N by planting time. Main plots were no-tillage and stubble mulched maintained for three years. Sub-treatments in the first year were wheat, chickpea and fallow, each split again for 0, 50 and 100 kgN/ha as ammonium nitrate. All plots were sown to wheat in the second and third years without additional fertiliser.

Some data were selected from wheat-wheat treatments in 1992 after long fallow from experiments at Croppa Creek and Warialda where long term effects of tillage and residue management on wheat production have been studied on a grey brigalow clay, and black earth. They comprised three main treatments (no-till, stubble burned after harvest and cultivation, and stubble mulching), split for eight sub-treatments devoted to variations in agronomy.

Measurements included soil coring prior to planting for nitrate-N and soil moisture content to 1.2 m. grain dry matter and N yield. Available water was the sum of available soil water at planting and rainfall from sowing until the end of October. Rainfall was recorded by growers until 1992 when automatic weather stations were installed. Little moisture remained in the profile by the end of October, and so the sum of available water at planting and in-crop rain approximated crop evapotranspiration. Total soil N and organic C were not measured.

Results and discussion

Grain yield and available water when nitrogen is not limiting

The relationship between grain yield and available water from high N fertility treatments, plus selected Queensland data are shown in Fig. I. A line of slope 12 kg/ha/mm with zero intercept delimited most of the data (4). Most points fell beneath the line, showing that WUE_g was often less than 12. The real issue is whether 12 kg/ha/mm is an achievable WUE in this environment where available water ranged from 200 to 500 mm; this will need additional corroboration.

A target yield can be determined from WUEg, the amount of water in the soil near planting, and an estimate for in-crop rain. Furthermore, we are interested in producing grain with high protein content, 11.5% or higher, so we really wish to target a protein yield, or more specifically a GNY; for example, targeting a crop yield of 3 t/ha and 11.5% protein content (2.0% N) is equivalent to targeting a GNY of 60 kgN/ha. We then turn to the relationship between GNY and soil nitrate-N at planting to determine whether the latter was sufficient.

Grain nitrogen yield and soil nitrate-N

GNY and soil nitrate-N were closely related, resembling a classical grain yield-fertiliser response curve (Fig. 2). The N-limited early phase can be treated as linear, by excluding the leverage due to data within the asymptote domain (Fig. 2, A-B and D-E), resulting in a regression with slope, NUE_g of about 0.5. Although the data in Fig. 2 provide limited evidence, they are consistent with a view that the asymptote yield, largely limited by water represents the target yield. A NUEg of 0.5 is conveniently simple, and indicates that at a minimum, twice as much nitrate-N was required at planting as was recovered in grain. A lack of water would reduce NUE_5 to zero in the limit. when grain yield reaches an asymptote.

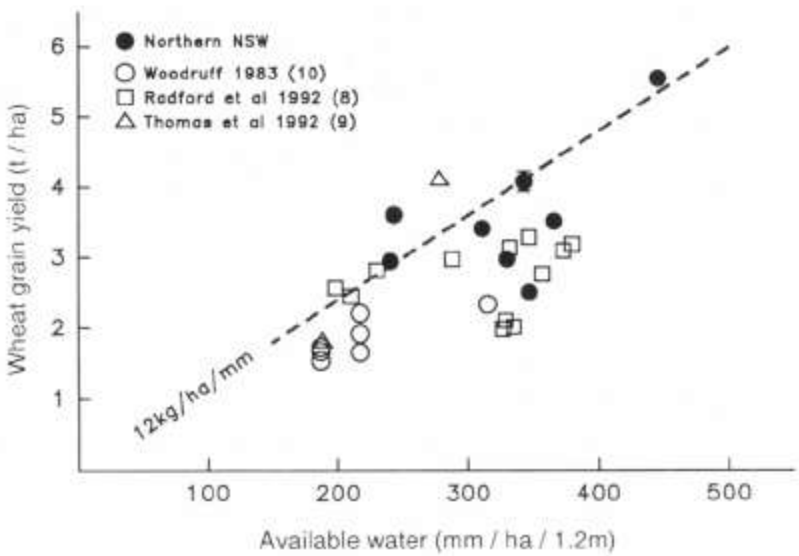

Figure 1. Relationship between wheat grain yield and available water for high N treatments in northern NSW experiments and additional data from Queensland sources.

In commercial practice

Management of water and N nutrition in a wheat-wheat system could be improved by:

- Selecting a yield target (from WUE , soil water at planting and expected in-crop rain).
- Defining the grain protein level. anti therefore GNY sought.
- Using NUE_2 to determine a minimum crop N need (Fig. 2, A-C and D-F).
- Estimating N fertiliser application from the difference between crop N requirement, and current soil nitrate-N fertility level (from previous crop GNY, or soil test).

Extreme seasonal variability makes it impossible to accurately predict rain in this environment, so growers may also be well served by choosing an amount for in-crop rain based on their experience and attitude to risk. An iterative budgeting procedure for N fertiliser will also be needed, taking into account GNY outcomes of previous year's N inputs before determining those for the current year.

Other research needs with regard to N-fertilisation include:

- Strengthening of the predictive value of previous year's GNY as a bio-assay of soil nitrate-N status in a wheat-wheat system.
- How to determine current soil-N fertility level in legume-wheat rotations as well as wheat-wheat systems.
- Estimation of the residual effect, or efficiency of carryover, of fertiliser applied in excess as a result of over-fertilisation in a dry year.
- Better information on the efficiency with which fertiliser and legume N contribute to soil nitrate-N supply.

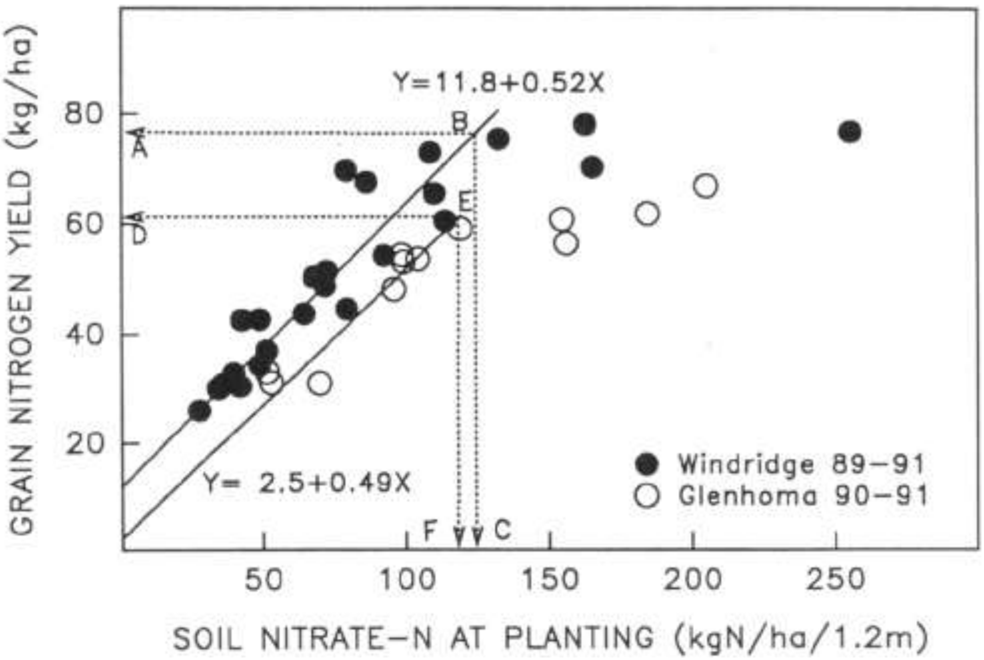

Figure 2. Relationship between grain nitrogen yield and soil nitrate-N at planting for Windridge and Glenhoma.

For the North Star area, experience indicates that most likely yield targets will be in the range 2.5 to 3 t/ha. If 11.5% grain protein content (GNY from 50 to 60 kgN/ha) for example, is set as a target, at least 100 to 120 kg/ha of nitrate-N will be needed in the root zone at planting. Therefore, at their current fertility levels, the Windridge and Glenhoma fields would need 80 and 60 kg/ha of extra N. either from fertiliser or legume to meet a yield target of 3 t/ha.

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