INTERPRETATION AND VALUE OF SOIL NITRATE NITROGEN AT DEPTH

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Summary. Deep soil coring conducted during 1993/95 often revealed high concentrations of nitrate nitrogen (bulges) at depth (below 60 cm). This may have stemmed from a series of crop failures brought about by the extended period of drought in Queensland. Routine sampling of farmers' paddocks to depth (below 60 cm) is now promoted as a way to keep track of this nitrogen. Deep nitrogen has been variously valued: (1) as equivalent to the cost of the nitrogen, as fertiliser, contained in the bulge; (2) in terms of the dollar value of the yield and protein response to its presence; and (3) as the savings in outlays on fertiliser nitrogen arising from a knowledge of its presence. Simulation studies suggest that the presence of nitrate nitrogen at depth can impact favourably on crop growth, but this does not provide a case for its routine measurement. The value of the nitrogen located in bulges at depth, and the value to farmers of knowing if it is there are different.

INTRODUCTION

Over the last 40 years, Australian wheat yield has increased at a much lower rate than in most other wheat producing countries. This has been attributed to a chronic shortage of nitrogen (N) (2). To a large extent, the decline in fertility and lack of N are a product of an industry coping with dramatically declining terms of trade, with farmers responding by cropping more frequently without legume ley phases for fertility restoration.

Farmers wishing to avoid N deficiency have access to a variety of tests and indicators which can guide their nitrogen fertiliser use. These include: reference to records of wheat production and protein content as a bioassay of a paddock's capacity to supply nitrogen to a planned crop (8); soil tests of total nitrogen (7); nitrate nitrogen in the surface soil, and to depth (4); and sap nitrate (3). Soil nitrate content (0-60 cm) has been used commercially to identify nitrogen-responsive paddocks in Victoria, New South Wales and Queensland. In Victorian research (P. Ridge, unpubl. data), there was close correspondence between the uptake of nitrogen by wheat and estimates of the soil N supply, using the approach of Myers (6).

However, good agreement between estimates of soil N supply, and its uptake by crops after the event, does not, by itself, lead to more profitable application of N fertiliser; interpretation of these data to effect changed action is also essential. Hence, while a soil test can indicate how much nitrogen is present at sampling, and how much is likely to become available under the crop, it cannot be converted to a fertiliser recommendation without the use of a model (whether intuitive, rule of thumb or computer) which takes into account seasonal effects on both the supply and demand sides of the equation (1).

As part of the evaluation of APSIM (Agricultural Production Systems Simulator) as a learning/decision support tool on-farm, the Agricultural Production Systems Research Unit (APSRU) has monitored the crops and soils in the paddocks of cooperating farmers. The APSIM models require detailed input data for soil variables in order to calculate the yields of crops. The soil monitoring involved taking cores to depth (1.8 m) to measure available soil water and nitrate N. Coring to this depth in the period 1993-95 revealed unexpectedly high concentrations of nitrate N (typically 50-150 kg/ha N in the 60-90 cm layer) below 60 cm, which has been a standard depth for commercial sampling of nitrate. It is not clear whether the high concentration of nitrate at depth is a common occurrence, or a product of the 1991-95 drought in Queensland. Irrespective of its cause, APSRU has promoted sampling to greater depth (90 cm) in order to gauge more accurately the total supply of available N in the root zone of crops.

THE VALUE OF DEEP NITROGEN

Initially, the N located deep in the profile was simply valued by researchers as its fertiliser equivalent. Hence, an 80 kg N/ha bulge at depth was valued at $64/ha ($0.8/kg N) irrespective of its location. An alternative approach valued it in terms of the increase in yield and protein that could be expected from its presence. Early discussions with farmers, as part of the on-farm project, suggested that its value should be discounted in comparison to applied N fertiliser. The degree to which it should be discounted was thought to depend on the time needed for the roots to reach and access the bulge of N at depth. Intervening dry layers, or insufficient N in the upper layers to support early crop growth, were cited as important factors.

These ideas were evaluated using the wheat crop simulation model within APSIM which could account for the amount and location of N in the soil profile. The simulation study, using 21 years of weather data for Dalby, showed that an 80 kg/ha bulge of N at a depth of 60-90 cm, against a low level of background nitrate (50 kg/ha of N, 0-60 cm), could increase wheat yield and protein content sufficiently to return an additional $400/ha, on a soil profile that was wet to 1.8 m. However, the impact of the bulge on yield and protein diminished rapidly once it moved below 1 m, and it was negligible at 1.8 m. The response to deep N was less on a drier soil profile due to the lower potential yield and restrictions to root penetration.

An alternative approach, also evaluated with the model, was to value the 80 kg/ha of N at depth in terms of the amount of fertiliser needed in the seed-bed to obtain a similar response. An 80 kg/ha bulge in the 60-90 cm layer was found to be, at best, equivalent to 55 kg/ha of N applied at sowing as fertiliser (31% discount). As the bulge moved deeper its value, in fertiliser equivalents, diminished (Table 1). This effect was more marked in drier soil profiles.

Table 1. The fertiliser equivalent of an 80 kg/ha N bulge at depth. Results of simulation study on wheat at Dalby. (averages for 21 seasons)

	Depth of Bulge		
Soil Water at Planting	60-90 cm	90-120 cm	120-150 cm
Full Profile	55 kg/ha N	38 kg/ha N	30 kg/ha N
Half Full Profile	35 kg/ha N	23 kg/ha N	12 kg/ha N

THE VALUE OF KNOWING SOIL NITRATE NITROGEN

Routine soil tests for nitrate nitrogen can highlight opportunities for profitable use of N fertiliser. In some situations (e.g. after drought), it can also identify opportunities to reduce outlays on N fertiliser. A knowledge of nitrate N should help managers ensure that their crops fully exploit this reserve before it leaches deeper in the profile.

The major difficulty in using soil tests of nitrate N to guide fertiliser decisions is the uncertainty that surrounds the coming season and its impact on the N requirements of crops. In the northern grain-belt, growing season rainfall can be expected to vary by about 60 mm around the mean (deciles 2.5 to 7.5). This corresponds to uncertainty in wheat yields of +/- 700 kg/ha around the expected yield, assuming a water use efficiency of 12 kg/mm for wheat (5). Growers targeting wheat of 13.5% protein face a variation in their theoretical N requirement of +/- 35 kg/ha N. This assumes a N use efficiency (recovery of soil and applied N in grain) of 0.5 for the production of grain at 11.5% protein: the N use efficiency is assumed to fall to 0.3 in raising the protein content from 11.5 to 13.5% in crops as they approach their water-limited potential yield (5). Given the over-riding effect of season on N requirement, there is little to be gained by adopting soil sampling procedures that aim at a precision better than +/- 35 kg/ha N. In the light of this, the error arising from ignorance of an 80 kg/ha N bulge at depth is relatively small (Table 1).

In 57 experiments conducted over five years in northern New South Wales, Holford and Doyle (4) found that the amount of nitrate N determined by sampling to greater depth (90 cm) closely reflected the N used by the crop. However, the results from shallower samples (0-15 cm and 0-60 cm) were useful indicators of the fertiliser N needed to grow 90% of maximum yield. Indeed, results from 0-15 cm samples proved to be statistically superior to those based on deeper samples in indicating the N fertiliser requirement.

The nitrate N content of samples collected as part of the APSRU on-farm programme on the Darling Downs in 1994 varied from 20 to 300 kg/ha (0-90 cm). In many cases, the amount in the whole profile (0-90 cm) was twenty times as much as the amount in the surface (0-15 cm), and there was no correlation between these two amounts. Hence, the use of surface samples would lead to a gross underestimate of the N available to the crop, and an overestimate of the fertiliser needed, under conditions favouring the accumulation of a N bulge at depth.

On the other hand, the nitrate contained in the 0-60 cm layer was somewhat more consistently related to that contained in the 0-90 cm layer. In the New South Wales studies (4), samples to 90 cm contained 25% more nitrate N, on average, than samples taken to 60 cm. In our studies we found 5 cases (of 40 examined) where inclusion of the nitrate N from the 60-90 cm layer increased the estimate of the N available to the crop by at least 80% (average 130%). In none of these cases was the estimate of nitrate N in the top 60 cm less than 70 kg/ha (average 103 kg/ha N). Even without additional data on soil nitrate at depth, this suggests that, after allowance for mineralisation under the crop, there would be at least 100 kg/ha N readily available to these crops. Excessive N fertiliser applications would therefore be restricted to those cases where farmers judged 100 kg/ha N to be inadequate for their purposes - for example if they were targeting high yields (>2.5 t/ha) of high protein (>12%) wheat.

DISCUSSION AND CONCLUSIONS

The main argument for soil sampling is to identify situations where the application of a nutrient will be profitable. In responsive situations, the application of N fertiliser will produce returns (increased yield and protein) equal to 3-5 times the outlay on fertiliser. Therefore the opportunity cost of under-application can be high.

Soil sampling can also be used to identify opportunities for savings in fertiliser costs. This can be particularly useful where producers are under financial pressure and cash flow is tight - for example after drought. In this case, limited finance can be directed towards more profitable opportunities. However, the economic consequences of over-application of N fertiliser are not as severe as those arising from under-application. This is because N applied in excess of the crop’s needs can be recovered, at least in part, by subsequent crops, so long as it does not leach beyond the root zone (typically 120 cm) in the intervening period. Sometimes an excessive supply of N can reduce yields by stimulating early growth to such an extent that it exhausts the water supply prematurely. However, because N located at depth will not be accessed until late in the season, it is unlikely to have this effect on early growth and water use.

The argument for sampling deeper is to identify the extent of reserves of nitrate N that may have accumulated through a series of crop failures, so that this can be factored into the calculation of fertiliser requirement. Our findings suggest that this N can lead to higher yields, particularly if the soil profile is also wet to depth. However, ignorance of this deep reserve rarely results in serious economic loss for producers.

Once the producers appreciate the potential value of soil nitrate information, the costs of sampling and chemical analyses for nitrate pale into insignificance. However, cost can be an issue for first time users of this type of information. The procedure recommended by APSRU involves sampling to 90 cm and splitting cores into 0-15, 15-60 and 60-90 cm segments. This costs about $160/paddock. This procedure allows bulges of N below 60 cm to be detected so that they can be allowed for (at their discounted value) in the calculation of the fertiliser requirement. However, a cheaper procedure, which involves a single mixed sample from cores to 60 cm, would be just as efficient in identifying responsive situations, and would be considerably cheaper because of time savings in handling core segments, and reduced analytical costs. Other things being equal, a soil testing procedure costing half as much as the currently recommended procedure is likely to be more widely adopted. The use of a cheaper and simpler procedure is likely motivate many more farmers to consider the use N fertiliser than is currently the case. The economic benefits that flow from this change in behaviour are likely to be much larger than the short-term savings, to be realised through deeper sampling, amongst those few growers who have a history of excessive applications of N fertiliser.

There may still be a case for deep sampling to establish the full extent of soil water reserves prior to planting. But we need to establish this case based on the frequency of more profitable decisions flowing from this knowledge. As for soil N, we should not overlook simpler and cheaper procedures than that currently recommended, in order to highlight the widespread opportunities for more profitable use of N fertiliser. The cost of additional information about N at depth is justified only if things are done differently as a result.

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REFERENCES

1. Blair, G. and Lefroy, R. 1993. Aust. J. Exp. Agric. 33, 1045-1052.

2. Hamblin, A. and Kyneur, G. 1993. Trends in wheat yields and soil fertility in Australia. (Dept. of Primary Industries and Energy; Bureau of Resource Sciences: Canberra).

3. Handson, P. D. and Sheridan, J. 1992. Proc. Intern. Conf. on Fertiliser Use in the Tropics, Kuala Lumpur.

4. Holford, I.C.R. and Doyle, A.D. 1992. Aust. J. Soil. Res. 30, 683-694.

5. Marcellos, H., and Felton, W .L. 1993. Proc. 7th Aust. Agrononomy Conf., Adelaide. pp. 111-114.

6. Myers, R.J.K. 1984. Fertiliser Res. 5, 95-108.

7. Tuohey, C. L. and Robson, A. D. 1980. Aust. J. Exp. Agric. Anim. Husb. 20, 220-228.

8. Woodruff, D. R. 1992. Aust. J. Agric. Res. 43, 1483-1499.