Controlling nitrogen losses - can we learn from the European experience?

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Abstract

The EU Nitrates Directive 91/676/EEC states that "Nitrogen pollution from agriculture has been identified to pose a risk to the quality of European ground, surface and marine waters." Its objective is to reduce risks via a reduction and a limitation of nitrogen application per hectare of arable land." In Australia the risk associated with excess nitrogen from agricultural sources is well recognised. However, nitrogen inputs and losses in agricultural systems are not regulated or monitored uniformly like they are e.g. in Germany.

In Australia, crop monitoring results, obtained over the past four years using N-check™ tests, have shown that this soil nitrate analysis and interpretation method, developed in Europe over the past 20 years, can be applied to Australian agriculture. It offers a way to minimise the movement of nitrogen from agricultural activities into waterways to protect downstream water quality and ecosystem health. At the same time it provides a valuable crop management tool.

Key Words

Nitrogen, soil test, water quality, crop quality, N-check

Introduction

The quantity of nitrogen needed by plants depends on various parameters such as crop type, fertiliser type, application season, agricultural practice (crop rotation), soil conditions, irrigation, etc. The combination of all these factors makes it difficult to estimate the exact quantity of fertiliser needed for certain crops. When fertilisers are applied in excess of the amounts plants really need, the surplus tends to leach to surface or groundwater. Between 10 to 60% of fertilisers are not used by the target plants. In some parts of Europe, agriculture is responsible for more than 80% of nitrogen emissions to aquatic ecosystems (EPI 2001).

Above a certain level, nitrates in water can endanger human health, and adversely affect the stability of ecosystems and aquatic life (nutrient enrichment of water bodies, soil acidification, etc.). Nitrates are considered to be the single most important limiting nutrient in the process of coastal and marine eutrophication (nutrient enrichment).

Methods

Review of the European and Australian approach to nitrogen management

A review of information from research, regulatory bodies and agricultural practice in the EU and Australia has been conducted to compare systems and approaches. This paper gives a summary using examples.

Field trials and data from commercial crops

The soil nitrate analysis and interpretation method used in Europe was tested in replicated field trials. A wide range of commercial crops was monitored for soil nitrate levels since 1997. This paper will present an example from a Russet Burbank potato crop, on a duplex soil, planted after combining two paddocks with different previous crops, (pasture and lucerne).

Results

Review of the European and Australian approach to nitrogen management in Agriculture

Recognizing the problem - Europe

The EU Nitrates Directive, 1991, states that “Nitrogen pollution from agriculture has been identified through research evidence to pose a risk to the quality of European ground, surface and marine waters. Risks relate to the high levels of nitrates found in drinking water, eutrophication of surface and coastal waters and acidification of soils and waters. The EU Nitrates Directive 91/676/EEC restricts the use of nitrogen in artificial fertilisers or manure to 170 kg/ha in nitrate-sensitive areas. The Directive 80/778/EEC on Drinking Water indicates a recommended nitrogen level of 25 mg/l and maximum concentration of 50 mg/l. The Directives ask for water quality and nitrogen in agricultural systems to be monitored.

Addressing the problem though indicators for actual and potential water pollution - Europe

The EU advocates monitoring of three indicators to achieve an improvement in water quality.

- **Indicator 1** - average concentration of nitrogen in surface and groundwater. This indicator provides information on the magnitude of the problem and changes over time.
- **Indicator 2** - intensity of fertiliser use, including organic and recycled materials, on agricultural soils to monitor potential pressures on water resources from run-off and leaching. Showing the spatial distribution of fertiliser use, this indicator can help targeting problem areas by introducing measures that achieve a balance between the application of nitrogen fertilisers and their uptake by crops.
- **Indicator 3** – Crop nitrogen budgets based on crop uptake and removal figures in combination with soil and plant analysis to estimate the exact quantity of fertiliser needed by plants. This indicator can assist in preventing excess nitrogen amounts to leach to surface or groundwater at an on-farm level.

Indicator 3 is not straightforward. The quantity of nitrogen fertiliser required and the risk of leaching vary with agro-ecosystem conditions (e.g. soil type & condition, climate), cropping patterns & practices, and season. They all influence the actual nitrogen uptake of crops, N-inputs through precipitation, the mineralisation of soil organic matter (humus, crop debris, manure etc) and losses through denitrification and volatilisation. Advance methods and models of N-budgeting have taken agro-ecosystem conditions into account.

Still, the rigour of estimating crop fertiliser requirements differs between EU countries (Rahn et al, 1997). Five of fifteen countries do not yet have a nationally uniform advice system. Four use combinations of fertiliser trials, yields, tables and balance sheets to estimate N-fertiliser needs. Six countries base recommendations on soil nitrate measurements in the root zone prior to an intended fertiliser application (Nmin). Fertiliser recommendations are then made considering target yield, expected N mineralisation and crop nitrogen uptake until the next topdressing or harvest. In England and Germany computer models have been developed. The aim of the Nmin based systems is to avoid N-losses from the root zone and limit nitrogen residues in the soil at harvest, while optimising yield and quality.

Walther et.al. (1998), compared Nmin based systems with other methods of estimating N-fertiliser requirements. The objective was to improve estimates without soil testing, through including agro-ecological and farm management information. After analysing data from 822 plots they concluded that the Nmin method was the most reliable nitrogen management tool.

In Germany, regulatory bodies have introduced a recording system of farm nutrient balances to monitor and manage N-inputs and outputs associated with all agricultural practices. The soil nutrient balance is calculated via plant uptake figures for each crop category, soil nutrient levels and nutrient inputs and outputs. Environmental conditions (soil structure, climate, seasonal variations, etc.) are considered to address the critical issue of surplus or deficiency of nutrients in the soil for agricultural and environmental management. Since 2001 German farmers have to keep adequate records on their farm nutrient balance under the Fertiliser Act (Duengeverordnung, Table 1). Together with water quality monitoring, the German system has implemented the three above-mentioned indicators.

Table 1 Farm nitrogen records to be kept under German the Fertiliser Act (2000)

Nitrogen input	Nitrogen removal
Nmin (pre-plant soil test)	Crop N removal with harvest (yield x crop N-content)
Organic and mineral fertilisers	Removal through stock (estimated via stocking rates)
Recycled organic materials	Feeding-off or removal (sales) of crop residues and green crops
Animal manure	Sales of manure
N-fixing legume crops	N-losses (denitrification & volatilisation) when spreading manure (20% of total)
Crop residues and green crops	

Recognising the problem - Australia

Even though Australian authorities have not regulated nitrogen inputs, the potential risk associated with nitrogen from agricultural sources is very well recognised. The National Land and Water Resources Audit found that, of 50 basins investigated, 36 exceeded nitrogen levels for ‘good water quality’(National Land and Water Resources Audit, 2002). The NSW Environmental Protection Authority summarises the problem in the following statement: “Most of the nutrient load in inland rivers is from diffuse sources such as rural and urban lands, rather than point sources such as sewage treatment plants and industrial processes. Unless diffuse sources are addressed at the same time as point sources, the health of inland rivers and streams is unlikely to improve.”

The Fertiliser Industry Federation of Australia Inc (FIFA) states; “there is a growing awareness of off-farm impacts of fertiliser use, particularly as this relates to catchment management procedures, and an emerging awareness of the lack of informed nutrient use efficiency as it impacts upon Australian agriculture, (or lack of comprehensive data on nutrient use efficiency).” The FIFA Nutrient Management Working Party has extensively reviewed the current research on the modes of transfer of nutrients from agricultural land to waterways and sub-surface water resources, and the development of best practice in nutrient management. This information is being developed into a database as a reference for the industry. The Working Party has identified the need to translate research findings into a framework for decision making by fertiliser users” (Fertiliser Industry Federation of Australia, Inc.). Kirkegaard (2002) stated that the cost of nitrogen mismanagement and poor water use exceeds $500m annually in lost production, foregone marketability and soil degradation.

Managing the problem in Australia

Amongst others, the Goulburn-Broken Water Quality Working Group and the Department of Natural Resources and Environment, Victoria, have published recommendations on when and how to apply fertiliser to minimise drainage losses. These recommendations however, do not include references to an appropriate monitoring system. CSIRO, Plant Industry, is working toward a better understanding of the relationship between nitrogen and water levels in plants and soils with the aim of effective use of resources. The CSIRO has developed decision support software (maNage Rice - together with NSW Agriculture, and maNage wheat). It uses individual crop, paddock and weather data to determine nitrogen requirements. Still, in most crops, the decision on the timing and amounts of nitrogen fertiliser applications are based on experience, field trial results, uptake figures and sometimes plant analysis. Nitrogen sources such as mineralisation of organic matter and crop residues and fertiliser carry over from previous crops are usually not considered. There still is a need to better align best crop management practices with environmental requirements e.g using agreed indicators and uniform recording systems.

While authorities in Australia do not regulate nitrogen input into farmland and nitrate levels in food at the moment, this may change with the introduction of Environmental Management Systems. According to European experience, an appropriate soil monitoring method will then be needed as part of an agro-ecological model.

Field trials and data from commercial crops

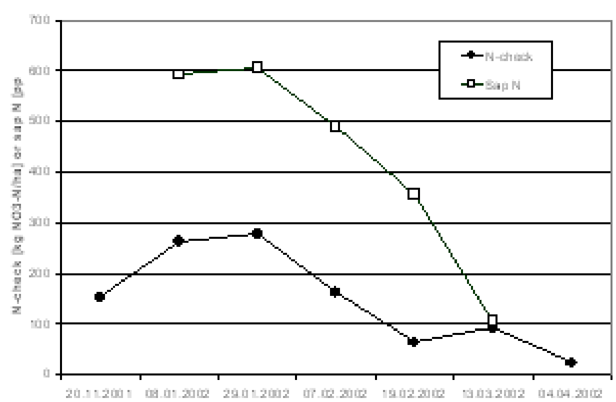
The European Nmin method (N-check) was evaluated in vegetables, hops and poppies in Tasmania since 1998. It was selected based on the results it has delivered to European agriculture and the environment. Some agricultural benefits were, improved post harvest performance, reduced disease incidence, better management of protein and sugar levels and reduced fertiliser costs (Stohmeyer, personal communication). In Germany, nitrogen fertiliser inputs declined since the mid 1990ies, they are still increasing in Australia (Fertiliser Industry Federation of Australia Inc).

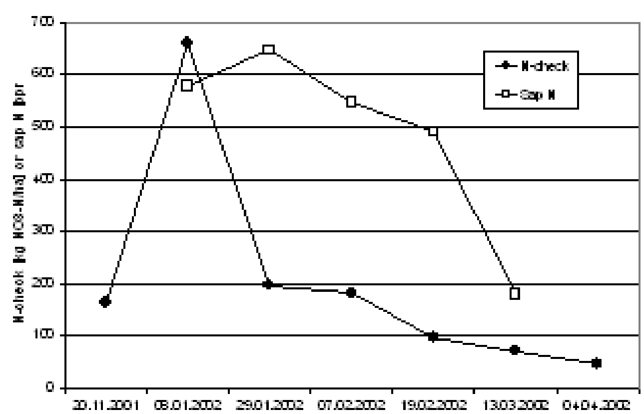
One of the major findings from field trials and monitoring of commercial crops was the need to include N-sources such as organic matter and crop residues into nitrogen budgets. Graphs 1a and 1b show an example of soil nitrogen release as influenced by different previous crops, pasture and lucerne. The pasture and lucerne paddocks were combined under one centre pivot irrigator prior to planting potatoes in October 2001.

Graph 1 Sap (ppm) and soil nitrate (kg/ha, 0-30cm) levels, Russet Burbank potatoes

a) after pasture

b) after lucerne





The difference in nitrogen release from pasture and lucerne highlight the need for monitoring soil nitrate levels as a basis for fertiliser recommendations if leaching has to be controlled. Additional consideration of dry matter production, N uptake during each crop growth stage and agro-ecological factors has the potential of increasing fertiliser use efficiency and crop quality while avoiding water pollution.

Conclusion

The use of a crop monitoring system based on European methodology has the potential to reduce nitrogen fertiliser use through matching nitrogen sources from soil and outside sources with plant uptake.

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