Targeted inputs make sense

CSIRO research is making it possible for farmers to use nitrogen more effectively and economically, benefiting them financially and helping the environment, as John Angus, Terry Bolger, John Kirkegaard and Mark Peoples report.

Farmers can save money and help the environment by targeting fertiliser nitrogen applications to ensure the correct quantity is applied at the correct time.

CSIRO research is revealing more about the timing of crop nitrogen demand and the amounts and timing of nitrogen supply from soil, fertiliser and pasture and crop residues.

Trials have shown perennial grass residues speed soil nitrogen mineralisation while continuous cropping reduces mineralisation rates. In addition, researchers found cultivation and stubble management have no significant impact on mineralisation.

Optimum nitrogen management means balancing crop nitrogen demand with the supply from soil and fertiliser.

Farmers can use the balance between soil nitrogen supply and crop nitrogen demand to calculate nitrogen fertiliser requirements using tools such as the Lime and Nutrient Balance software package.

When calculating nitrogen supply, there are four main sources to consider: soil organic matter mineralisation; decomposition of recent pasture and crop residues; non-symbiotic nitrogen fixation; and fertiliser.

Soil organic matter mineralisation

CSIRO researchers measured rates of net mineralisation using on-site incubations during the life cycle of crops growing on red earths and red–brown earths in southern New South Wales. These experiments were in the early years of a cropping phase, generally 3–6 years after pasture.

The average mineralisation rate was 0.1 per cent of total nitrogen in the top 100 millimetres of soil under optimum temperature and soil water conditions. For example, if the top 100mm of soil contained 1% organic carbon, and the carbon:nitrogen ratio was 10, it contained 0.1% total nitrogen, equivalent to 1400 kilograms of nitrogen per hectare.

At a glance

- New information about soil nitrogen supply shows higher mineralisation rates after perennial grasses than after other pasture types.
- Mineralisation in continuous cropping systems is lower than after pastures.
- Cultivation and stubble management have no significant effect on mineralisation rate.
- The balance between soil nitrogen supply and crop nitrogen demand can be used to calculate nitrogen fertiliser requirement. Useful tools such as the Lime and Nutrient Balance package are available.

For most dryland crops it is preferable for nitrogen to be delivered to the crop gradually.

Mineralisation under optimal conditions was 1.4kg of nitrogen/ha/day (0.1% of 1400). The mineralisation rate was close to zero at an average temperature of less than about five degrees Celsius in dry soil.

A limitation of this approach was measuring organic matter.

Jan Skjemstad and colleagues in CSIRO have shown organic carbon could be overestimated with conventional tests that could not distinguish between inert graphite and genuine organic matter.

Graphite is a product of prehistoric vegetation burning and is found in large amounts (20–40% of the total carbon) in soils that carried old grasslands such as the cracking clays of northern NSW. Red soils that carried woodland typically contain less graphite. Scientists are developing improved tests of organic carbon but meanwhile total nitrogen is a more reliable estimate of soil organic matter.

Another limitation is that mineralisation rates appear to decrease after long periods of continuous cropping.

After 14 years of continuous cropping in an experiment at Harden, NSW, the daily rate of mineralisation, as a percentage of the total nitrogen present, was 30% less than the rate measured after 3–6 years of cropping. This decrease was in addition to the decrease

Photos: CSIRO

Nitrogen taken up early by the crop leads to vigorous seedling growth.

due to a fall in total organic matter and suggests the quality of organic matter also decreases.

Residue decomposition

The effects of temperature and soil water are similar for mineralisation of residues and soil organic matter.

The difference is that residues can decompose faster than 'old' soil organic matter, particularly if they have a low carbon:nitrogen ratio.

For example subclover root residues can have a low carbon:nitrogen ratio and decompose rapidly while the surface roots of lucerne have a high carbon:nitrogen ratio and their residues decompose slowly.

But the fine roots of lucerne, which are typically 0.8–1-metre deep, have a lower carbon:nitrogen ratio and probably decompose more rapidly.

Research shows that residues of the perennial grasses, phalaris and cocksfoot, have surprisingly high mineralisation rates (see Figure 1).

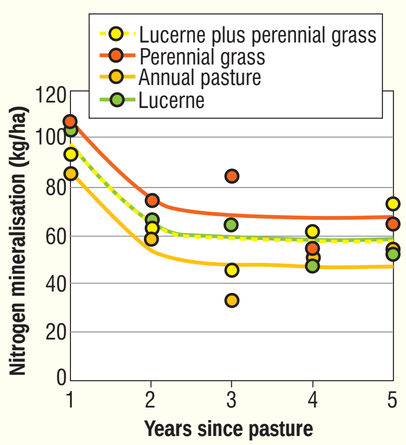
This is consistent with high levels of mineral nitrogen following a pasture containing perennial grasses.

When lucerne and perennial grasses are grown together, the roots of perennial grass may recover nitrogen mineralised in the subsoil and recycle it to the soil surface.

Mineralisation of crop residues is generally slower than mineralisation of pasture residues. Several independent experiments show management of soil and stubble has surprisingly little effect on mineralisation.

Table 1 shows one such dataset after 13 years of continuous wheat–broadleaf crops comparing cultivation and stubble management. This result is consistent with measurements that show no difference in the

FIGURE 1 Nitrogen mineralisation



Source: CSIRO.

TABLE 1 Nitrogen mineralisation measured in paddocks over 68 days*

Stubble burnt		Stubble retained	
cultivated	direct drilled	cultivated	direct drilled
26.3kg/ha	26.6kg/ha	31.6kg/ha	23.3kg/ha

* During autumn, after 13 years of soil management treatments in an experiment at Harden, NSW.

Source: CSIRO.

$$\frac{\text{Target yield (t/ha) x target grain protein (\%)}}{\text{Harvest index for nitrogen (\%) x correction factor}}$$

$$\text{Example: } \frac{3.5 \times 11.5}{75 \times 0.0057} = 94\text{kg/N/ha}$$

rate at which soil organic matter decreased after different systems of cultivation and stubble management.

Other mineral nitrogen sources

Non-symbiotic nitrogen fixation can contribute to total nitrogen, particularly in nitrogen-deficient soils, where free-living soil microbes use energy from the residues of soil organic matter, crops and pastures to convert atmospheric nitrogen to the protein in their cells. This process can occur during both crop growth and fallow.

The conditions for rapid non-symbiotic nitrogen fixation are warm temperatures (above 20–25°C), wet (not moist) soil and a supply of carbon.

Under optimal conditions, the annual non-symbiotic nitrogen fixation can be about 20kg/ha. Non-symbiotic nitrogen fixation does not contribute directly to the mineral nitrogen used by crops and is measured as mineralisation.

Some ammonium can be released from clay interlayers, particularly in shrinking-swelling soils. This ammonium is not measured in routine soil tests. It is most likely to be significant after a period of saturation.

Another nitrogen contribution is about 1kg/ha for every 100mm of rainfall.

Fertiliser availability

The availability of mineral nitrogen from fertiliser can depend on placement in the soil and time of application.

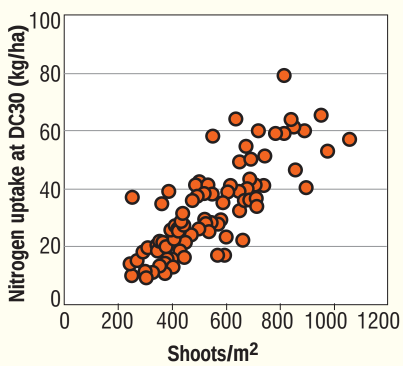
Fertiliser nitrogen is normally rapidly available but is released slowly when urea or anhydrous ammonia is banded in high concentration such as by injecting between every second row (mid-row banding), so that each row of seed has access to fertiliser on only one side.

Slow-release fertilisers such as granular urea with additives to inhibit microbial activity or a slowly soluble plastic coat are becoming available. These products were expensive because they were released primarily to reduce nitrate pollution in Europe, Japan and North America where cost was unimportant because of government subsidies to farmers.

In southern grainbelt areas, mid-season top-dressing is an effective way to manage nitrogen supply in cereal crops, provided there is sufficient rainfall.

Opportunities for efficient top-dressing are limited in northern areas because of infrequent rainfall during the most effective periods between the mid-vegetative and booting phases.

FIGURE 2 Nitrogen and shoot density*



* Relationship between shoot density at the start of stem elongation (DC30) and the amount of nitrogen in the above-ground parts of the crop at the same time. The data are from experiments on farms in southern NSW.

Source: CSIRO.

Estimating nitrogen supply

The variation in soil mineralisation is less predictable before sowing than during crop growth.

A pre-sowing soil test helps make accurate decisions about fertiliser nitrogen at sowing. When paddock performance and seasonal conditions are predictable check only a few paddocks in an area to guard against surprises. When there are unusual seasonal conditions or unusual pasture and crop sequences, carry out more tests.

A soil-nitrogen test is generally less reliable than mid-season tests on the crop such as a shoot density test (see Figure 2).

Crop nitrogen demand

In most cases variation in crop nitrogen demand is more than variation in soil nitrogen supply.

Given this variability one approach is to estimate targets based on historical results. The equation above calculates nitrogen demand for the grain plus straw.

The example is for a target yield of 3.5 tonnes/ha and target protein of 11.5%. The harvest index for nitrogen is the percentage of crop nitrogen in the grain and the correction factor converts protein to nitrogen (divide by 5.7) and the units to kgN/ha.

Crop nitrogen demand varies with crop management such as time of sowing, disease and the supply of other nutrients.

Recent results suggest grazing can have conflicting effects on nitrogen demand. On the one hand grazing vegetative wheat leads to removal of nitrogen so it could be important to replace this nitrogen to recover yield.

In one recent experiment researchers found the efficiency of topdressed nitrogen was lower on grazed than on ungrazed crops, possibly because grazing reduced the energy available for nitrogen uptake from the soil.

Mid-season shoot density tests are more reliable indicators of nitrogen availability than pre-sowing soil tests.

Timing of nitrogen demand

Nitrogen taken up early by the crop leads to vigorous seedling growth.

Advantages of vigorous seedlings are weed suppression and reduced water loss through evaporation.

Disadvantages are increased risks of disease, lodging and haying off.

For most dryland crops it is preferable for nitrogen to be delivered to the crop gradually.

Slow nitrogen delivery is particularly important where there are subsoil limitations that restrict the available soil water capacity and make the crop susceptible to haying off.

Grain protein increases relatively more than yield when nitrogen is delivered to the crop late in the crop cycle.

The two large sources of supply are soil nitrogen that previously leached into the subsoil and topdressed fertiliser.

In favourable spring conditions topdressing can produce large yield and protein responses. The conditions that suit this double response are rainfall soon after topdressing and a continuing supply of soil water, either stored from earlier in the season or late rainfall.

Matching supply and demand

CSIRO and NSW Department of Primary Industries produced a useful tool to help farmers balance nitrogen supply and demand.

The tool, known as the Lime and Nutrient Balance, is based on the results presented in this article and can be ordered from www.grdc.com.au/lnb.

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