BACK PADDOCK SoilMate

ORGANIC CARBON AND OTHER FACTORS AFFECTING NITROGEN MINERALISATION RATES.

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It is a frequent point of discussion among agronomists whether mineralised N estimates should be included in cropping N budgets and the accuracy of various mineralisation estimates. This paper discusses the process of mineralisation and puts it into context with the N budgeting process.

Mineralisation is a term that describes the oxidative conversion of an element from an organic compound to a mineral state. Most nutrients involved in plant nutrition are made available to plants to some extent by the mineralisation process. The importance of mineralisation in providing a plants nutrient requirement is dependent on both soil and crop growth factors. The term net mineralisation describes the amount of mineral nutrient available to a crop after the effects of other soil processes such as immobilization, adsorption and precipitation.

In the broadacre cropping soils of southern Queensland and NW NSW the nutrients most influenced by mineralisation are nitrogen (N) and sulfur (S) with lesser dependence for phosphorus (P) and zinc (Zn) in some soils.

Nitrogen mineralisation is the conversion of organic N to ammonium-N (NH_4^+). Organic soil N occurs as proteins, amino acids, amino sugars and other more complex compounds. The proportion of the total soil N in these various fractions is as follows: bound amino acids 20 – 40 %; amino sugars, 5 – 10% and purine and pyrimadine derivatives, 1% or less. Very little is known of the chemical nature of the 50 % or so of the more complex compounds not found in these fractions. Mineralisation of organic N involves two reactions, aminization and ammonification, which occur through the activity of heterotrophic microorganisms. These organisms require a source of organic C compounds for energy to fuel the mineralisation process. Aminization is the process whereby proteins are converted to amino acids while ammonifcation is where amino acids are converted to ammonium. Following mineralisation of N is the nitrification process where ammonium is converted to nitrate (NO_3^-).

The initial high N fertility of the vertosols of SE Queensland and NW NSW is as a result of the N rich organic matter of the soils in their virgin state. Soil organic C of >2 % and total N of 0.15 to 0.2 % (C/N ratio 10/1) were common across the region (Dalal and Mayer 1986b, Dalal and Mayer 1986e). In some vertosol soils inert carbon compounds such as charcoal may be present in significant quantities (up to 70 %), pushing the soil C/N ratio to 15 to 20:1 in some cases.

The most commonly used measure of soil organic matter is the Walkely-Black organic carbon (C) test in which the soil carbon fraction oxidised by dichromate is measured. In converting organic carbon % to an estimate of organic matter the organic C measurement is multiplied by 1.6 to 1.9. The factor varies according to the analytical method used and the source of the organic material.

The process of nutrient depletion that has occurred through the region has not always affected the organic carbon and total N content of the soil equally (Dalal and Probert 1997). Hence use of organic C as a surrogate for total N may lead to unreliable estimates of organic N available for mineralisation.

Factors Affecting N Mineralisation

Soil Moisture

Soil moisture content is one of the most important factors in the process as it regulates the aerobic and anaerobic microbial activity. Maximum aerobic mineralisation activity occurs between 50 and 70 % water filled pore space (Havlin et al. 1999). Soils moist enough to grow crops will generally have enough moisture for normal mineralisation. Excessive moisture can lead to poor soil oxygenation that slows mineralisation and nitrification, and decreases net mineralisation due to increased denitrification.

Temperature

Mineralisation begins at temperatures just above freezing point and the rate increases as the soil temperature increases to 25 to 30^{o}C (Havlin et al. 1999). Above this temperature range mineralisation rate decreases.

Soil Organic Matter

Soil organic matter contains about 5 % N and during a 12 month period generally 1 to 5 % of the organic N is mineralised. As the soil organic N content increases, the quantity of N mineralised increases. The can be estimated quantity of N mineralised for a given period of time can be estimated based on knowledge of the soil organic C or total N %, the quantity of the N mineralised for a given time-step and the environmental conditions that existed or are forecast to occur. Soil organic matter is generally quoted as having a C:N ratio of about 10:1.

Importance of N Mineralisation in Estimating Crop Requirement

The two important factors in N mineralisation for cropping are the timing of the major mineralisation events, and the net quantity available for crop growth.

Timing

With soil temperature and moisture being the most influential parameters in mineralisation patterns of rain-grown crops peak mineralisation rate is usually determined by the interaction of climate and soil texture. Mineralisation is greatest when the soil is warm and moist and slowest when cool and/or dry.

In the northern parts of Australia, mineralisation is most rapid during summer due to the summer dominant rainfall (Figure 1), whereas further south mineralisation tends to have a bimodal pattern, peaks occurring in autumn and spring, winters generally being too cold and summers too dry for rapid mineralisation.

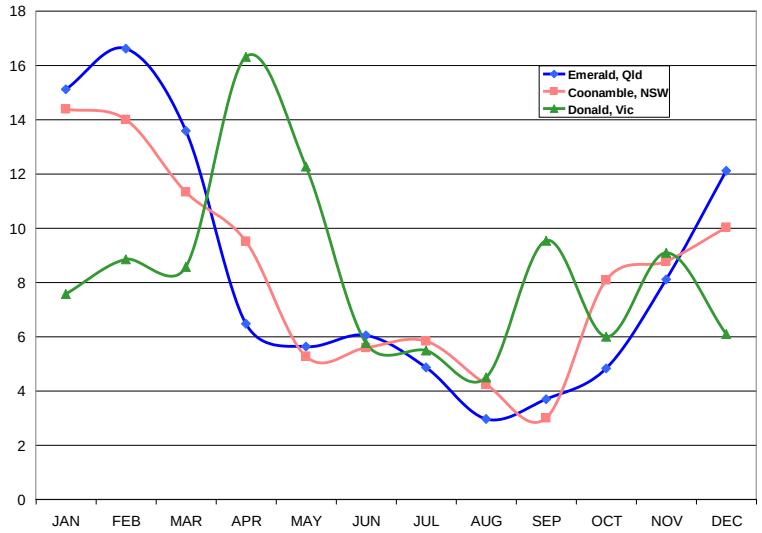

Figure 1. Annual mineralisation patterns for three locations in eastern Australia

Net Quantity

During mineralisation, N is liberated from a number of organic pools. These pools can coarsely be divided into those "old" relatively stable release sources and more volatile crop residues. The ratio of %C to %N of the soil and residues incorporated determines the amount of N available for crop use.

Generally, when organic substances with C/N ratios greater than 30:1 (2% N) are added to soil, soil N is immobilised during the initial decomposition process (Figure 2). For ratios between 20 and 30:1, there may be neither immobilisation nor release of mineral N. If the organic materials have C/N ratio less than 20:1 (1.5% N) there is usually a release of mineral N (Havlin et al. 1999).

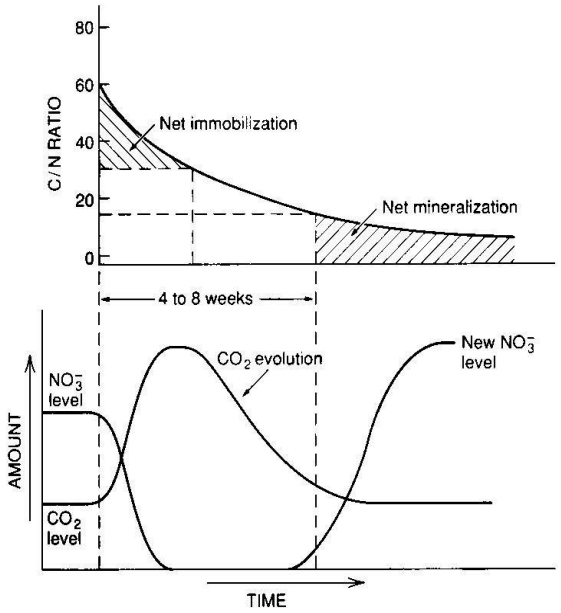

Figure 2. Changes in NO_3^- levels of soil during the decomposition of low N crop residues (from Havelin et al. 1999).

Methods of Estimation of Mineralisation

Estimation of mineralisation can be made from detailed soil models of C and N cycling in daily time-steps e.g. APSIM (Table 1, Figure 3) to simple seasonal or monthly apportioning of lookuptable values (Nitrogen in 95) (Table 2).

Goondi	5 years	15 years	25 years	40 years
January	27	21	15	12
February	30	22	16	14
March	27	20	15	13
April	19	15	11	10
May	13	10	8	7
June	8	6	5	4
July	7	5	4	4
August	8	6	5	4
September	11	8	7	6
October	17	12	10	8
November	20	15	12	10
December	24	18	14	12

Table 1: Monthly potential mineralisation rates (kg/ha) at **Goondiwindi.**

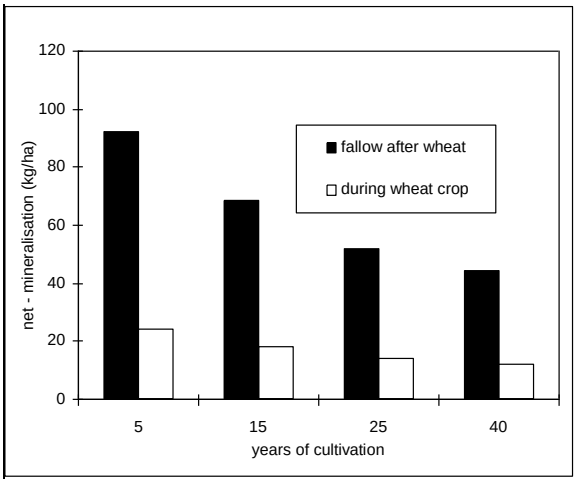

Figure 3: Estimated actual mineralisation for a continuous wheat rotation at **Goondiwindi.**

Table 2. Estimated annual mineralised nitrogen (kg/ha N) for a range of soils of southern Queensland.

Age of Cultivation (years)	Black Earth	Box	Brigalow	Belah
1	99	88	109	99
5	76	62	87	89
10	60	51	70	79
20	44	46	54	61
30	39	46	49	48
40	38	46	48	46
50	37	46	47	30
75	37	46	46	18

Conclusion

Essentially whether or not mineralisation should be included into an N budget is dependent on the potential quantity mineralised in comparison to the total crop requirement and the accuracy of other crop parameter estimates. For a winter cereal in the northern cereal belt, annual mineralisation can commonly supply up to 100 % of crop requirement in "new" soil however in older soil the supply may be as little as 20 %. For N budgets, in-crop mineralisation may account for less than 10 % of the total requirement. Given that yield estimates in budgets are commonly of low accuracy, it is common for growers to ignore in-crop mineralisation in making crop N decisions, the major quantity from summer mineralisation being detected in pre-sowing soil analyses.

Mineralisation patterns for the different climatic zones indicate the importance of selecting the timing of soil analysis to correspond with a point in the fallow where mineralisation potential has been maximised if mineralisation is to be left out of consideration in a crop N budget.

In the southern cereal belt and for summer cereals N mineralisation in-crop is frequently a large proportion of the crop N supply. Under these circumstances N mineralisation requires careful consideration in planning a nutrition program.

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