EFFECT OF VARIOUS MANAGEMENT SYSTEMS ON N MINERALISATION IN SURFACE SOILS

K.I. Paul[1], A.S. Black[1] and M.K. Conyers[2]

[1]School of Agriculture, Charles Sturt University, Wagga Wagga, NSW 2678
[2]Wagga Wagga Agricultural Institute, NSW Agriculture, Wagga Wagga, NSW 2650

Abstract

The mineralisation of N within surface soils (0-15 cm) has been found to decline with depth. Both the rate and possible causes of the development of surface soil gradients of net N mineralisation were investigated in this study. During various times of the year (March 1996, December 1996 and May 1997), surface soil layers were sampled from fallow, wheat and subterranean clover plots from a field trail which commenced after surface soil mixing in March 1996. Each of these soil layers were then incubated in the laboratory to determine their relative rate of net N mineralisation. It was found that initially net N mineralisation rates were relatively uniform with depth within the surface 10 cm. Relatively uniform mineral N accumulation with depth persisted in the absence of plants. However, in the December and May samples 58 to 69% of total net N mineralisation to 15 cm depth originated from the surface 5 cm soil sampled from under plants. This suggests that gradients of net N mineralisation developed in response to increased available substrate on the soil surface due to plant residue return at the completion of the growing season.

Key words: N mineralisation, soil layers, originates.

Net N mineralisation rates decline with depth within surface soils (0-15 cm) in southern NSW (4, 7). It has been demonstrated during both field and laboratory studies that about 85% of the total N mineralised to 20 cm depth originated from the surface 6 cm while only 1 to 7% originated from the soil below 10 cm (4). Under five different pasture soils the surface 6 cm contributed between 70 and 92% of the total N mineralised within the surface 10 cm (7). Similar observations have been made in Western Australia (3, 5) and overseas (1, 6) when net N mineralisation was investigated in 5 cm depth intervals.

Gradients of mineral N production within the surface soil may limit agricultural production in two main ways. Firstly, during the period of rapid plant growth in late spring, the N rich soil surface begins to dry and thus become inhospitable to plant roots. Under such conditions the majority of the soils available N might not be productively utilised by the plant. Secondly, gradients of mineral N production within surface soils places the fertility of soil at risk. The loss of the surface 2 cm due to erosion would result in a 55% and 35 to 67% decline of potential N supply for crop and pasture respectively (4, 7).

Although gradients of net N mineralisation have been identified, little is known about how they develop. The objectives of this study was to determine how rapidly these gradients develop and how management factors influence their formation.

Materials and methods

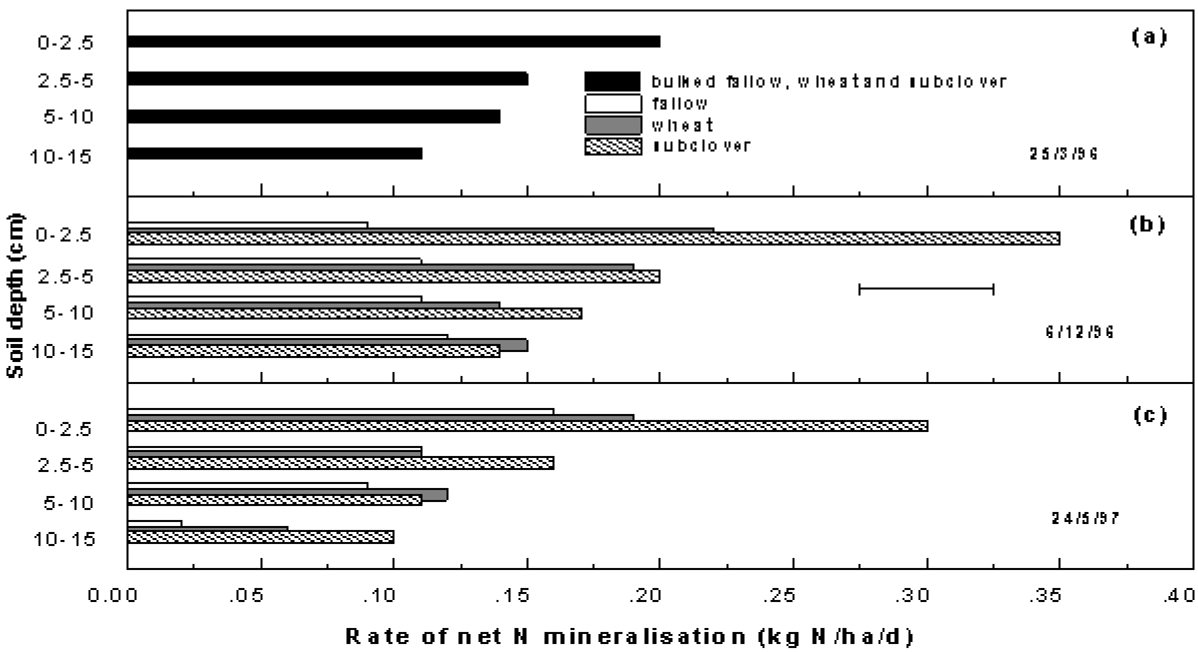
In March 1996 a field experiment was established on a red earth (Red Kandosol) soil at Charles Sturt University farm, Wagga Wagga. Three replicate plots of fallow, wheat and subterranean clover were arranged in a randomised block design. At the commencement of the experiment the surface soil was mixed to at least 7.5 cm depth with a rotary hoe.

Nine replicate soil samples were taken from fallow, wheat and subterranean clover treatments in March 1996, December 1996 and May 1997. These samples were bulked in 0-2.5, 2.5-5, 5-10 and 10-15 cm layers, air-dried (40^{o}C) and sieved (2 mm). As plants had not been sown by March 1996 soil from all plots was bulked at this sampling time.

Four 40 g replicates of each soil layer were incubated (at 20^{o}C and 90% field capacity) in sealed incubation jars for seven weeks. Each week jars were opened to maintained oxygen and soil moisture content. The rate of net N mineralisation during the incubation was calculated by monitoring the production of mineral N (NH_4^+-N and NO_3-N) during the seven week period.

Soil mineral N accumulation within incubated surface soil layers were analysed by extracting 40 g of soil with 200 mL of 1M KCl. After shaking for one hour soil extracts were filtered (Whatman 5). Soil mineral N content of the filtered soil extracts were analysed using an ALPKEM auto analyser.

Results and discussion



In March the total rate of net N mineralised in the surface soil was 0.60 kg N/ha/d. As a result of soil mixing, the rate of net N mineralisation was relatively uniform to 10 cm depth (Fig. 1a).

Total net N mineralisation rate declined by 0.17 kg N/ha/d in fallow surface soil sampled in December. Net N mineralisation remained relatively uniform with depth in the absence of plants (Fig. 1b). The presence of plants increased total net N mineralisation by 0.11 to 0.26 kg N/ha/d. This was attributed to the 0.06 and 0.20 kg N/ha/d increase in net N mineralisation rates in the surface 5 cm of soil from under wheat and subterranean clover, respectively. Hence, by December management treatments had a significant effect on soil net N mineralisation rates in the surface 5 cm. The rate of net N mineralisation within the surface 5 cm of soil sampled from under wheat and subterranean clover were almost 2 and 3 times greater respectively than that observed in fallow soil. Furthermore, within the surface 2.5 cm of soil the rate of net N mineralisation was significantly greater under subterranean clover than wheat. Thus, in contrast to fallow soil, there was a substantial decline of net N mineralisation rates with depth in surface soils sampled from under wheat, and particularly under subterranean clover.

Relative to mineralisation rates observed in December sampled soils, total net N mineralisation rates declined by 0.06, 0.23 and 0.19 kg N/ha/d in May sampled surface soils from under fallow, wheat and subterranean clover respectively. This may be attributed to the depletion of available substrate. Nevertheless, relatively uniform rates of net N mineralisation to 10 cm depth continued within fallow surface soil while net N mineralisation rates significantly declined with depth under subterranean clover (Fig. 1c). The only significant difference in net N mineralisation rates between management treatments was observed in the surface 2.5 cm of soil. At this depth net N mineralisation rates in soil sampled from under subterranean clover were almost 2 times greater than that observed in fallow soil.

Between October and December 1996 dry matter yields decreased by 1.7 and 4.1 t/ha under wheat and subterranean clover, respectively. It was assumed that this was due to leaf fall. Return of this plant residue to the surface of the soil increases the availability of substrate within the surface 5 cm. Hence, although relatively uniform rates of net N mineralisation were observed with depth, within fallow surface soils, an average of 58% (63%) and 64% (69%) of total net N mineralisation to 15 cm depth originated from the surface 5 cm of soil sampled from under wheat and subterranean clover in December (and May), respectively.

The percentage of N mineralised from residues is controlled by their C:N ratio. The C:N ratios of subterranean clover and wheat residues in December were 15:1 and 52:1, respectively. It follows that gradients of net N mineralisation rate with depth were more pronounced under subterranean clover than under wheat.

Most studies which have investigated gradients of net N mineralisation with soil depth have been conducted in relatively undisturbed soils (1, 2, 3, 4, 5, 6, 7). In such studies, it has often been observed that total C and N and thus, net N mineralisation, declined with soil depth (7). Results obtained in the present study show that in the presence of plants, gradients in net N mineralisation develop with depth in one growing season, even when soils were initially mixed.

Conclusion

Net N mineralisation gradients in the surface soil appear to develop in response to the addition of available substrate to the surface of the soil with plant residue return. Hence, even after surface soil mixing, gradients of net N mineralisation will develop under crop and pasture systems during late spring and summer when plants commence haying-off. These gradients do not develop in the absence of plants.

The extent of surface soil gradients of mineral N appears to depend on the plant residue quality. Gradients of net N mineralisation may be particularly pronounced under legume based pastures. This may be attributed to the low C:N ratio of plant residues produced by this systems.

Gradients of mineral N production which develop during summer within surface soils under plants, may persist until the commencement of the following growing season. It is therefore conceivable that over consecutive growing seasons, gradients of mineral N availability may become more pronounced as the availability of substrate within the surface 5 cm of soil accumulates. This would be particularly evident under pasture and cropping systems where residue is retained. After consecutive seasons under these systems it may be beneficial to mix and thus redistribute the available substrate within the surface soil. This may minimise potential N lost to plant uptake and erosion during the subsequent growing season.

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