SOIL NITROGEN AND PASTURE MANAGEMENT

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Abstract

The seasonal pattern of nitrogen mineralization is described and compared with the potential demand for nitrogen by grasses. Peak mineralization rates occur in spring but are quite inadequate for expression of potential grass growth. Nitrogen fixation by clovers provides a significant input into the system over a short period. Consideration of the fate of fixed nitrogen shows that losses largely offset this input unless it is maintained at a high level. The role of pasture management and fertilizer practice in this maintenance is stressed. Seasonal differences in nitrogen transformations and their influences on nitrogen losses are discussed.

INTRODUCTION

NITROGEN DEFICIENCY limits pasture production severely during the entire growing season in Southland. It is true that nitrogen deficiency, during part of the growing season at least, is an obligatory condition of legume-based pastures, but the extent of deficiency and the effects of farming practices on it deserve some discussion.

Three nitrogen cycle processes, namely, nitrogen mineralization, nitrogen fixation, and transformation of nitrogen, are discussed in this paper. These are not the only important processes but are those most satisfactorily researched at present. Other processes, such as denitrification, enter the discussion but no attempt is made to fully resolve their involvement here.

All the data used in this paper were gathered at the Grasslands Division Regional Station at Gore, the soil type being Waimumu 'silt loam. Extrapolation of these results to other E-gleyed yellow grey earths in the region is believed to be valid.

NET NITROGEN MINERALIZATION

Net nitrogen mineraiization is the process by which about 2 or 3% (Allison, 1973) of the large quantity of soil nitrogen (> 3000 kg/ha — 15 cm in Waimumu) is rendered available to plants annually. In Southland mineralization is a more or less continuous process with no major breaks. The lower line in Fig. 1 shows the daily rate of nitrogen uptake by a grass sward, and

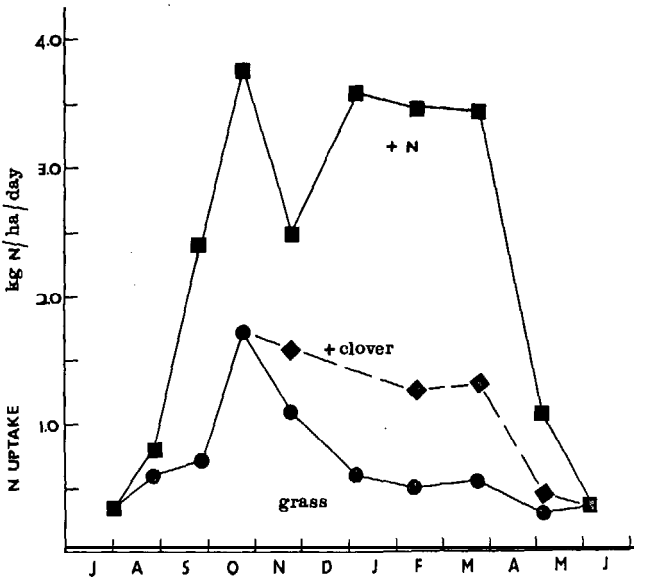

FIG. 1: *The seasonal patterns of nitrogen uptake by grass swards, grass/clover swards, and grass swards not liimted by nitrogen deficiency.*

this quite closely reflects the rate of mineralization, deviating only by the amount of mineralized nitrogen lost from the soil. Little variation from a uniformly low rate occurs except for a period of about ten weeks in spring. During this burst of activity the basic rate is trebled, and, although brief, it provides the nitrogen for the spring flush. Growth is influenced over a longer period, however, as the nitrogen mineralized enters the grazed soil-plant system where a decreasing proportion of it remains active for some time.

Comparison of the nitrogen uptake by a grass sward and that of a sward that is not limited by nitrogen deficiency (the upper line, Fig. 1) shows that even the highest rates of mineralization are quite inadequate to allow grass to express its potential for growth.

Three factors control nitrogen availability in soils:

(1) The amount of substrate available.

(2) The balance between release of nitrogen from the substrate by the soil microflora and the removal, or immobilzation, of available nitrogen by the microflora.

(3) Losses of nitrogen from the soil.

The question of substrate formation is too complex to be discussed fully here. Balance between mineralization and immobilization varies seasonally and seems to be at least partially involved in the net nitrogen mineralization seen in spring. Under cool conditions the immobilization reactions are favoured and microbial protein synthesized (Russell, 1961). With the onset of warmer conditions, decomposition reactions may become more important. Holland and During (1977) report that immobilization of urine nitrogen apparently occurs in winter with a subsequent increase in nitrogen availability in spring.

Two important practical considerations arise from the pattern of events described. The first cannot be confidently assessed at present; that is, if immobilization of urinary nitrogen during winter is important in increasing spring nitrogen status, then wintering systems for stock will have important fertility consequences. Secondly, it is clearly recognized (Whitehead, 1970; Harris et al., 1973) that soil nitrogen is more efficiently used where long regrowth periods are allowed. Spring pasture management systems will differ in the extent to which they take advantage of the mineralization flush.

NITROGEN FIXATION AND CLOVER GROWTH

From the onset of winter until mid-October, clover and grass pastures behave substantially the same as a pure grass sward in terms of' both yield and nitrogen economy. Comparison of the lower two lines in Fig. 1 shows that a clover component does not seriously influence nitrogen economy until about the end of November. Clover growth rates peak between late November and March. Maximum rates of nitrogen fixation also occur during this period but, in general, no direct quantitative relationship between the two processes can be inferred (Carran, 1978). The restriction of clover growth to a period of quite severe nitrogen deficiency does, however, mean that only a small amount of clover growth can be made using soil nitrogen. The rest must be made on symbiotic nitrogen.

Though this coincidence can be regarded as fortunate, the restricted period of activity does make the system fragile. Moisture stress, to which nitrogen fixation is very sensitive, is more likely to occur during this period than any other. It is thus a major part of the annual contribution that is affected, not just a part. This is clearly shown in the data of Sinclair et *al.* (1976) where acetylene reduction (nitrogen fixation) rates were greatly reduced in the summer of the second, drier year.

In Southland pastures the quantity of clover herbage nitrogen produced is usually between 200 and 300 kg N/ha. A large proportion of this comes from nitrogen fixation. The commonly held viewpoint, that this represents an input of more or less available nitrogen, is, however, erroneous. Consideration of the fate of this nitrogen shows why.

Nitrogen entering the soil plant system through fixation is involved in the same chain of events outlined for mineralized nitrogen: plant growth, consumption, excretion, loss, or synthesis of microbial protoplasm, and so on. The principal difference is that, because of plant geometry, rather more of the clover tends to die and rot instead of being eaten than does the grass.

In a study of the nitrogen balance of urine patches at Gore during summer, Carran, Ball, Theobald, and Elder (unpublished) found less than 40% of urine nitrogen was recovered in herbage. Where much of the nitrogen fixed is eaten by animals, it is therefore ineffectively used and only of transitory importance.

Organic matter that has been recently added to soil is the source of a large proportion of the nitrogen mineralizing in the soil (Allison, 1973). Clover herbage nitrogen that is not eaten and eventually finds its way into the soil probably has a more enduring effect on soil fertility.

A considerable portion of the nitrogen in the rotting herbage therefore has a medium term effect on soil fertility (say, one or two years). A portion (the size of which probably varies with season, being greatest in winter) of the rotting material becomes more intimately involved in the reactions of soil organic matter. The nitrogen in this fraction is relatively resistant to break-down, becoming available only slowly over a period of very many years. Losses of nitrogen during rotting of plant material do occur, chiefly as ammonia (Allison, 1973; Denmead et *al.,* 1976). The size of this loss in this environment is unknown.

Seen in this perspective, it is clear that nitrogen entering the soil-plant system through fixation fairly quickly enters a number of pools of different size and availability (Table I). The effect of the grazing animal and litter cycling in mediating the balance between items 1 and 2 and 3 and 4 has been thoroughly discussed by Ball (1977). Unless nitrogen fixation is maintained at a high rate, little contribution to soil fertility is likely apart from the short-term effect of urine patch nitrogen. Pasture management systems must take this into account and recognize that the

TABLE 1: NATURE OF POOLS INTO WHICH FIXED NITROGEN ENTERS AND THE PROPORTION IN WHICH IT ENTERS

Pool	*Relative Size of Annual Input from Fixed Nitrogen*
1. Stable organic matter	small
2. Relatively labile organic matter	medium
3. Mineral nitrogen in urine patches	medium to large
4. Lost from system	large to very large

fertility of clover-grass pastures is as much a function of management as the innate properties of such associations.

Brougham (1970) has demonstrated the injurious effect of hard summer grazing on clover performance. Such grazing management will lead to lower nitrogen fixation and a higher proportion of the fixed nitrogen being lost as NH_3. Set stocking at a low rate must also be considered a "hard grazing" regime since it allows selective grazing of clovers.

On Waimumu and similar soils lack of attention to detail in topdressing programmes can have marked effects on clover performance. Molybdenum is of key importance in nitrogen fixation, as without it the fixation process cannot proceed. A systematic approach to molybdenum topdressing is needed on these soils to ensure that it is always in adequate supply.

Potassium use should also be directed at the clover component of pastures. Much potassium is wasted in Southland because it is applied at the wrong time. Ideally potassium should be applied at the start of the period of rapid clover growth. Potassium-deficient clover is a conimon sight during January and February where autumn application of K is practised.

TRANSFORMATION OF NITROGEN

In many respects this has the least direct importance of the three processes discussed. Grass growth is not influenced to any great extent by the ionic form of nitrogen that predominates (Ball, 1967). The way in which nitrogen is transformed in soils does, however, have considerable effect on the way in which nitrogen is lost from soils. Ammonium ions are the product of mineralization of organic nitrogen and hydrolysis of urea, and may be used by plants, adsorbed by colloids, immobilized, or oxidized to nitrite, and then to nitrate. It is the latter two anions that lead to losses by leaching and denitrification.

Incubation experiments using the method of Eno (1960), in which soil samples are enclosed in a plastic bag and buried under a turf for a period, have given a clear picture of the seasonal pattern of nitrogen transformation. From this the probability of losses, and some effects of management on losses, can be inferred. These patterns cannot be clearly seen in the field because of the simultaneous removal by plant uptake of both substrate (NH_4^+) and products (NO_2^-), (NO_3^-),

The oxidation processes, or nitrification, are inhibited by low temperature; an incubation during winter commonly yields about equal quantities of NH_4^+ and NO_3^- and a trace of NO_2^-. Increasing temperatures in the spring favour nitrification to the extent that no NH_4^+ accumulates during incubation. This pattern continues through spring and autumn. When suitable moisture and temperature conditions prevail, NO_2^- accumulates in quantities of 1 to 2 μg/g. indicating that simultaneous denitrification and nitrification are occurring.

As this appears common in the spring, any management system that does not allow complete utilization of the mineralizing nitrogen will predispose to losses through denitrificstion. Similarly, some denitrification of the unused NO_3^- in urine patches must be expected in spring and moist summers.

The failure of NO_2^- to accumulate during winter while NO_3^- does suggests that low temperatures inhibit denitrifying organisms.

SUMMARY

There are two important periods of nitrogen provision for grass or clover growth in pastures in this area:

(1) The period of relatively high mineralization rates in spring.

(2) The period of efficient nitrogen fixation during summer.

Farming systems can either operate in harmony with these, and benefit accordingly, or operate without regard to them. The consequence of the latter will be indifferent pasture performance as this approach will not always allow inputs to balance the inevitable losses from grazed pasture.

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REFERENCES

Alison, F. E., 1973. ***Soil organic matter and its role in crop production.*** In: ***Developments in Soil Science,*** 3. Elsevier, Amsterdam. 637 pp.

Ball, P. R., 1967. N.Z. ***agric. Sci., 1***: 21-2.

——— 1977. N.Z. ***Soil News: 25.***

Brougham, R. W., 1970. ***Proc. N.Z. Grassld Ass., 32:*** 137-48.

Carran, R. A., 1978. N.Z. ***Jl exp.*** Agric., 6: in press.

Denmead, 0. T.; Freney, J. R.; Simpson, J. R., 1976. ***Soil Biol. Biochem.,*** 8: 161-4.

Eno, C. F., 1960. ***Proc. Soil Sci. Soc. Am., 24: 277-9.***

Harris, A. J.; Brown, K. R.; Turner, J. D.; Johnston, J. M.; Ryan, D. L.; Hickey, M. J., 1973. ***N.Z. Jl exp. Agric., 1***: 139-63.

Holland, P. T.; During, C., 1977. N.Z. ***Jl agric. Res., 20: 479-88.***

Russell, E. W., 1961. ***Soil Conditions*** and ***Plant Growfh.*** 9th ed. Longmans, London. 688 pp.

Sinclair, A. G.; Hannagan, R. B.; Risk, W. H., 1976. N.Z. ***Jl agric. Res.,*** 19: 451-9.

Whitehead, D. C., 1970. The role of nitrogen in grassland productivity. ***Commw. Bur. Pastures Field Crops, 48.***