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Seasonal and fertiliser effects on microbial phosphorus and nitrogen in soils under pasture

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Abstract

Significant quantities of phosphorus (P) and nitrogen (N) are present in the soil microbes compared with pasture requirements for these nutrients. Seasonal and fertiliser effects on microbial P and N were investigated in a controlled environment (CE) experiment, two field trials and a glasshouse trial. In the CE experiment there was a basic seasonal pattern of storage of P and N by the microbial biomass over "winter" and release of these nutrients in "spring". Climatic variations affected this pattern in the field trials. Withholding fertiliser did not affect soil microbial P and N in the field trials, despite a decline in pasture production of up to 20%. Soil microbial P and N did decline in the glasshouse trial, in which a much larger drop in herbage production (>80%) was induced by nutrient deficiency.

Keywords soil microbial biomass, microbial phosphorus, microbial nitrogen, seasonal effects, withholding fertiliser, plant nutrients

Introduction

Soil microbes have a central role in nutrient turnover in soil. Significant amounts of phosphorus (P) and nitrogen (N) are also present in the microbial tissue. In New Zealand soils under established pasture, soil microbes contain 10-75 kg P/ha and 70-220 kg N/ha in the top 75 mm (Sarathchandra et *al.* 1984; Sarathchandra *et al.* 1988; Perrott & Sarathchandra 1989; Perrott et *al.* 1990).

We have investigated seasonal and fertiliser effects on a number of microbiological and biochemical factors in pastoral soils. In this paper we summarise our findings for microbial P and N from a controlled-environment (CE) experiment, two field trials and a glasshouse trial.

Methods

Controlled-environment experiment

Undisturbed cores of a Horotiu sandy loam (Typic Vitrandept) were taken from a Waikato dairy farm in June 1986. The soil cores (100 mm dia x 200 mm depth) were collected using cylindrical PVC sleeves. Pasture was trimmed to approximately 100 mm and the cores transported to the climate laboratory at DSIR Fruit and Trees, Palmerston North. Two CE rooms were used to simulate a "winter-spring" sequence based on typical Waikato soil temperatures. The temperature sequence used is presented diagrammatically in Figure 1. Periodically, cores were removed from the trial, herbage cut to soil level and microbial P and N measured in the top 75 mm of soil. Further details are given in Sarathchandra *et al.* (1989).

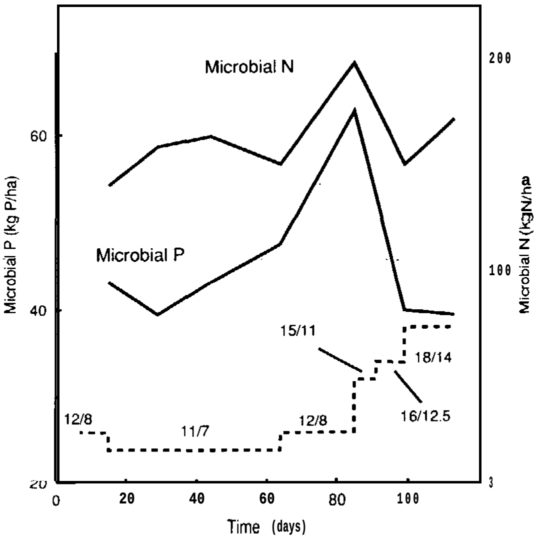

Figure 1 Microbial P (average SEM = 1.8) and N (average SEM = 5.4) in Horotiu sandy loam: controlled-environment experiment. The temperature sequence is represented by the dashed line (12/8 = 12 °C day temperature and 8 °C night temperature).

Field trials

One field trial was on a high-producing Waikato dairy farm (Sarathchandra et *al.* 1988; Perrott *et al.* 1990). The soil was Waihou fine sandy loam (Typic Vitrandept) under permanent grass-clover pasture. Microbial P and N were measured in soil samples (O-75 mm) collected at approximately 4-weekly intervals from paired fertilised (30% potassic superphosphate) and unfertilised plots during 1983 and 1984. The unfertilised plots had not received fertiliser (superphosphate) since 1977. Further details on this trial are given by Feyter et al. (1988).

The other field trial was on a hill country site at the MAF Te Kuiti Research Area (O'Connor *et al.* 1990). Unfertilised and fertilised (250 kg superphosphate/ha per year) paired plots were laid down on two paddocks having approx. 24” slope in August 1984; one paddock had an approx. easterly aspect, the other an approx. south-westerly aspect. The soil was Mahoenui silt loam, a central yellow-brown loam (Typic Dystrochrept) typical of 1.3 million ha of North Island hill country. Soil samples (0-75 mm depth) were collected at 4- to 7-weekly intervals from August 1984 to December 1986.

Glasshouse depletion trial

Samples (0-100 mm depth) of 7 soils (2 yellow-brown earths, 2 yellow-brown loams, a brown-granular clay, a yellow-brown pumice soil and an organic soil taken from under existing pasture) were sieved and thoroughly mixed then weighed into 500 g pots. Ryegrass (Ellett) was grown in these pots which were divided into 3 treatments: (i) Control — receiving all nutrients; (ii) No P — receiving all nutrients except P; (iii) No N — receiving all nutrients except N.

The trial was maintained with regular harvesting of herbage (approx 4-weekly) until the yields from the No P and No N treatments were less than 20% of the control treatments for each soil (approx. 12 months for the No N and 24 months for the No P treatments). The pots were then removed and soil extracted from the roots by sieving.

Microbial P and N

After sieving (< 4 mm) and thorough mixing, the field-moist soil samples from these trials were analysed for microbial P by a fumigation-extraction procedure (Brookes *et* al. 1982; Perrott & Sarathchandra 1989). Microbial N was determined by a similar method (Sarathchandra *et* al. 1988) using a k_N factor of 0.54 to correct for unextracted microbial N (Brookes *et al.* 1987).

Results and discussion

Seasonal effects

In the CE experiment, “seasonal” patterns for microbial P and N were similar. Both increased over the low temperature period and declined when the temperature increased (Figure 1). The declines were statistically significant, amounting to about 25 kg P/ha and 50 kg N/ha in the top 75 mm. These quantities of P and N are substantial if made available for plant uptake.

The seasonal patterns observed suggest that the soil microbial biomass is involved in the storage of nutrients over winter and then their release in spring when the nutrient requirements of pasture are at their highest. We have attributed the accumulation of microbial nutrients over. winter to increases in the bacterial component of the biomass relative to the fungal component as bacteria contain higher nutrient concentrations than fungi (Sarathchandra *et al.* 1988; Sarathchandra *et* al. 1989; Perrott *et al.* -1990).

Release of microbial nutrients in spring can be explained by grazing of bacteria by protozoa which is known to promote the release of P and N (Cole *et al.* 1978; Woods *et al* 1984). Grazing may be initiated by the higher bacterial activity in spring resulting from increased availability of root exudates as substrate for bacterial growth and improved environmental conditions at that time.

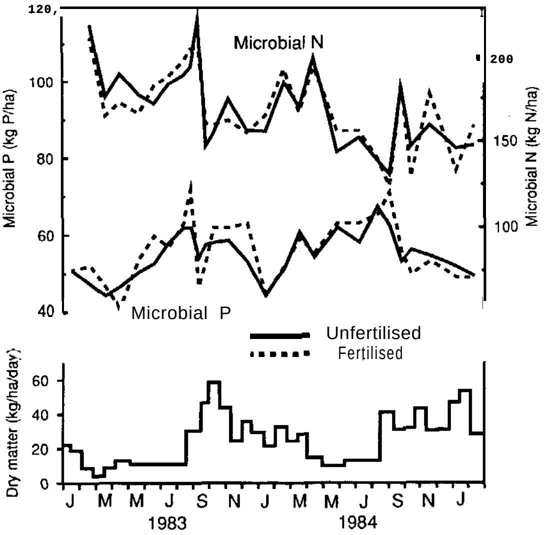

Figure 2 Microbial P (average SEM =2.7) and microbial N (average SEM = 8.2) in fertilised (------) and unfertilised (———) in Waihou fine sandy loam — Waikato field trial. Pasture production (average of fertilised and unfertilised treatments) presented in lower plot. Fertiliser applied in March 1983 and September 1983 and 1984.

Seasonal patterns of microbial P and N in the field trials (Figures 2 & 3) were not so clear. However, the basic pattern of accumulation over winter and decrease in spring was apparent for microbial P in both years of the Waikato trial (Figure 2). It also occurred for microbial N during the first year of the trial, although in the second year a large decrease occurred during winter. At the Te Kuiti site there were peaks of microbial P in summer as well as winter and minima in autumn as well as spring. The summer peaks corresponded to increased rainfall (Figure 3) and probably resulted from increased pasture growth and hence increased supply of root exudates as substrate for bacterial growth. Microbial N fluctuated throughout the year in this trial with a large decrease occurring in winter 1986.

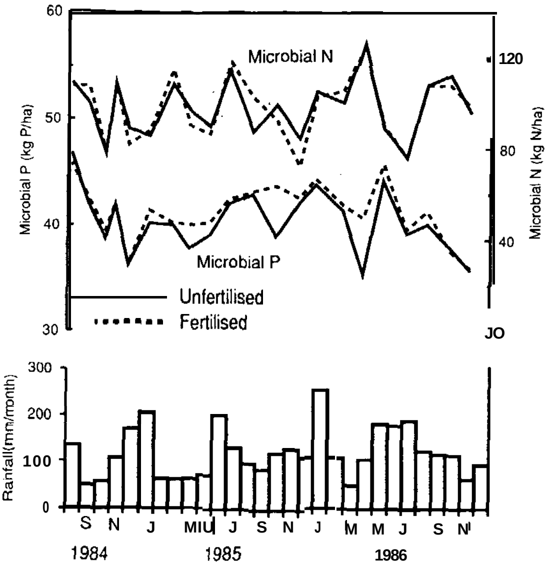

Figure 3 Microbial P (average SEM = 1 .O) and microbial N (average SEM = 2.6) in fertilised (------) and unfertilised (———) in Mahoenui silt loam - Te Kuiti field trial. Monthly rainfall presented in lower plot. Fertiliser applied in August 1984 and September 1985 and 1986.

It appears that the basic pattern of storage and release of nutrients by the microbial biomass seen in the climate laboratory experiment is modified by variations in climatic changes in the field. These climatic variations could have an indirect effect through changes in plant growth as well as directly by affecting environmental conditions for the soil microbial biomass;

Release of nutrients from the microbial biomass could be significant for plant nutrient uptake, particularly in spring. Table 1 shows that amounts of P released from the soil microbial biomass were similar to or even greater than the amount of P taken up by pasture at these times. N released from the microbial biomass ranged from 17 to 66% of total N uptake. The relatively smaller contribution of N from the microbial biomass compared with P could be because 25 to 50% of the total N uptake is clover N fixed from atmospheric N (Ledgard *et al.* 1987; 1990.

Table 1 Uptake of P and N by pasture and release from microbial biomass in unfertilised soil from 2 field trials.

Growth Period	Uptake (kg/ha)		Release from biomass (kg/ha)	
	P	N	P	N
Waikato Trial				
Sept 83 - Jan 84	18.0	198	17.5	38
Mar 84 - May 84	5.0	54	6.6	41
Sept 84 - Nov 84	10.5	113	7.7	22
Te Kuiti Trial				
Aug 84 - Nov 84	5.6	64.8	10.5	20.2
Jan 86 - Apr 86	4.5		8.5	
Aug 86 - Dec 86	6.4	73.5	4.4	12.5

Fertiliser effects

Although the unfertilised plots in the Waikato field trial had not received superphosphate for 6 years, the pasture production on these plots was still about 92% ($P < 0.05$) of that on the fertilised plots. In contrast, at the lower-fertility Te Kuiti site, superphosphate had last been applied in April 1983 and by spring 1986 dry matter production on the unfertilised plots was less than 80% of that on the fertilised plots.

There were no significant fertiliser effects on the soil microbial P or N in these two field trials.

Table 2 Effects of withholding P on microbial P and withholding N on microbial N in glasshouse trial.

Soil	Microbial P (μg P/g) Original	Plus P	No P
Hamilton	78.4	106.1	63.6
Horotiu	67.6	77.2	46.9
Mahoenui	80.8	91.3	26.8
Peat	80.3	134.3	63.4
Taupo	105.3	130.3	42.5
Te Kowhai	79.2	91.8	38.7
Wairama	74.0	83.0	26.8
Mean (as % of original)	100	126 SED = 4.4[a]	55 SED = 2.1[b]

[a] Comparing with No P or Original;
[b] Comparing with Original.

Soil	Microbial N (μg N/g) Original	Plus N	No N
Hamilton	214	194	135
Horotiu	294	258	154
Mahoenui	288	146	99
Peat	194	171	162
Taupo	215	271	114
Te Kowhai	249	162	100
Wairama	210	145	76
Mean (as % of original)	100	81 SED = 2.3[a]	51 SED = 2.7[b]

[a] Comparing with No N or Original;
[b] Comparing with Plus N.

Although inorganic P declined at both sites (Perrott *et* al. 1990), withholding superphosphate did not affect microbial biomass carbon, organic P or a number of other microbial and biochemical measurements we made (Sarathchandra *et al.* 1988; Perrott *et* al. 1990). Apparently, the pasture production declines in these trials had not been sufficient to affect the biological cycle and the amounts of microbial biomass.

In the glasshouse trial we found that soil microbial P for the pots provided with all nutrients was greater than in the original soils as taken from the field (Table 2). This probably reflects the removal of nutrient limitations and the improved environmental conditions (temperature, moisture). The high ryegrass growth and consequent return of organic matter to the soil via root exudates and the decomposition of dead roots explain the increase in soil microbial biomass and microbial P. In contrast, where the growth of ryegrass was inhibited by nutrient limitation, amounts of soil microbial P and N were smaller (Table 2). This was most probably due to reduced organic matter inputs to the soil resulting from reduced plant growth.

The absence of clover in the pot trial may explain the lower amounts of microbial N in the Plus N pots compared with the original soils.

Clearly, in the glasshouse trial the soils were subjected to more extreme depletion than in the field trials. The decline in ryegrass growth was extreme. Herbage production in the nutrient-deficient pots was less than 20% of that in the non-deficient pots by the time pots were removed from the trial for soil analyses. Presumably, in the field a longer period of withholding fertiliser is required before the organic cycle is sufficiently reduced to affect the soil microbial biomass and amounts of microbial P and N.

Conclusions

Compared with plant requirements and amounts added as fertiliser, substantial quantities of P and N are contained in the soil microbial biomass. Our experimental results show the importance of storage and release of P and N by the microbial biomass in the cycling of these nutrients. Phosphorus released from the microbial biomass in spring would make a substantial contribution to pasture uptake at that time. This could explain lower responses to fertiliser P in spring compared with other seasons. Topdressing in summer or autumn when responses are more likely could be a more efficient use of fertiliser P where spring release of microbial P is adequate for pasture growth?

Amounts of microbial P and N were not affected by the withholding of fertiliser in the short term, despite decreases in pasture growth of up to 20%. Eventually, decreases would occur as the reduced pasture growth affects the organic cycle.

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