THE EFFECT OF FERTILISER HISTORY ON NUTRIENT ACCUMULATION AND PLANT-AVAILABLE NUTRIENT SUPPLY IN LEGUME-BASED PASTURE SOILS

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ABSTRACT

Animal production in New Zealand is dependent on pastoral legumes to build soil nitrogen fertility, which otherwise limits the growth of the major sward component, grass. Traditionally, in order to sustain legume vigour, single superphosphate has been applied to elevate soil phosphorus and sulphur levels. Rarely have either the agronomic or nutrient efficiencies of these systems been assessed. Fourteen hill country pasture sites in three broad rainfall regimes were chosen to assess the effect of contrasting fertiliser histories on soil fertility, in particular nitrogen availability. At each site soil fertility indices and pasture production for the 1993/94 growing season were measured. Pasture production was strongly influenced by soil fertility and climate. Soil fertility was the dominant factor and of the soil fertility indices evaluated, Olsen P was the best predictor of pasture growth. Soil mineralisable N and the fraction of total N that was mineralisable were positively correlated to increasing soil P status.

KEYWORDS

Legumes, nitrogen, pasture, nutrient accumulation, phosphorus, sulphur, fertiliser

INTRODUCTION

In the temperate grasslands of New Zealand, nitrogen and phosphorus availability is often the key factor limiting pasture production (During, 1984). Traditionally, single superphosphate (SSP) , containing phosphorus (P) and sulphur (S) is applied to provide adequate fertility for the legume component of the sward to be the sole provider of nitrogen (N) by biological N fixation (Ball and Tillman, 1994). To investigate the efficiency of fertiliser use, or the sustainability of such practices, researchers must determine if traditional fertiliser policies have improved the fertility status of soils, and how improved soil fertility is related to pasture growth on an annual basis. Few studies (e.g. Nguyen *et al.*, 1989; Perrott *et al.*, 1989; Walker *et al.*, 1958), however, provide complete information on the changes in soil fertility and pasture productivity to make judgements. This paper examines the effect of historical SSP applications on nutrient accumulation and plant-available nutrient supply in grazed legume-based pastoral soils in hill country of the North Island, New Zealand.

METHODS

The study was conducted in the Wairarapa region (central and southern east-coast of the North Island, New Zealand). After extensive soil sampling in the region, fourteen trial sites were selected, and established on sheep and beef cattle hill country farms. Sites were selected on the basis of climate, having either "low" (800-900mm/yr), "medium" (1100-1200mm/yr) or "high" (1200-1400mm/yr) annual rainfall. Within each of these rainfall zones, sites with contrasting fertiliser histories ["low" (no fertiliser for 15-20 years), "medium" (125kg/ha SSP or equivalent for 15-20 years) or "high" (250+kg/ha SSP or equivalent for 15-20 years)] were selected. All sites had a slope of 10-20°, and were fenced (16m^2) to exclude dung and urine inputs (transfer), harvesting and site damage by grazing stock. Pasture production (rotated 0.5m^2 exclusion cages cut every 14-28 days) and soil moisture (cores 7.5 cm depth) were measured for the 1993-1994 growth season. The harvested pasture was then dried, and dry matter production calculated. Olsen P (Olsen *et al.*, 1954), and extractable (sulphate) S (Searle 1979), soil pH (2.5:1 water to soil ratio), mineralisable soil N (Waring and Bremner, 1964) and exchangeable cations (Schollenberger and Simon, 1945; Blakemore *et al.*, 1987) were measured on soil samples (cores 7.5 cm deep, dried, sieved <2mm) taken at each site. Total soil N and P were determined by Kjeldahl digest (McKenzie and Wallace, 1954), and total S by dry oxidation (Landers *et al.*, 1983). Soil total carbon (C) content was determined by the Leco combustion method (Bremner and Tabatabai ,1971).

RESULTS AND DISCUSSION

Soil phosphorus content ranged widely from 430µgP/g at a low fertility site, to 1470µgP/g at a high fertility site (Fig 1a.). The key factor influencing total P levels was fertiliser history. Long-term application of SSP resulted in a large (1000µgP/g) accumulation of P in the 0-7.5cm soil depth. Soil P accumulation was lower at the low rainfall sites, presumably because of lower fertiliser inputs, which reflects farmers recognising the lower productivity potential of these pasture systems given climate (rainfall) limitations.

Total soil N and S also accumulated as a result of increased P and S fertiliser application, but to a much lesser extent than soil P. Regression analysis revealed a poor relationship between total soil N and P (Fig 1b.), and showed only modest increases in soil N with increasing soil P. The N:P ratio varied from more than 10:1 to < 5:1 indicating the differences in the use of soil and fertiliser P in building the soil organic N pool. Total soil S was also poorly related to total soil P (Fig 1c.), and again showed a far greater accumulation of P than S, due probably to variable and greater S leaching losses. Climate also influenced N and S accumulation. Sites with high historical fertiliser inputs and low rainfall (e.g. site 8) had greater (total N and S) accumulation when compared to equivalent sites in high rainfall areas (e.g. site 1). This could in part be attributed to greater N and S leaching losses in areas of high rainfall (Lambert *et al.*, 1988).

Pasture dry matter production for the 1993/94 season ranged from 4 tDM/ha to 15.5 tDM/ha (Fig 2a.). Pasture production was influenced by both soil fertility status and climate, with soil fertility being the dominant factor. Olsen extractable soil P ranged from 10µgP/g to 82µgP/g, and reflected total P accumulation in soil from fertiliser and animal transfer. Of all measured soil fertility indices, Olsen P was by far the best predictor of pasture growth in the field, for periods where soil moisture was non-limiting. A strong Mitcherlich type relationship (Fig 2b., R^2=0.76) best explained the spread of data, suggesting that at high soil P fertility, factors other than soil P status are limiting pasture yield. Also, 95% of relative yield is obtained at an Olsen P of 35-40µgP/g at these sites. Elevation of soil P fertility (by additional fertiliser application) beyond 40 µgP/g is inefficient from a purely yield perspective, as beyond this P level only minimal yield increases occur. Herbage analyses of field samples have also revealed that no major or trace elements are limiting plant growth at high soil P fertility, although clearly there are some other factors limiting growth.

Soil mineralisable N levels ranged from 110 to 300 kgN/ha, and were linearly related to Olsen P (Fig 2c., R2=0.80). This contrasts markedly with the weak relationship between Olsen P and total soil N. It is apparent that as soil P fertility increases, the nature of the soil organic nitrogen changes, with an increasing proportion becoming readily mineralisable, and hence available to plants. The influence of soil P and S fertility on the rate of N cycling in the sward is as yet little understood.

CONCLUSIONS

Historical application of superphosphate at the sites examined in this study has resulted in large increases in total soil P, and lesser relative increases in total soil N and S. This increase in soil fertility has resulted in large increases in annual pasture yield on these soils, except where low summer rainfall limits potential growth. The best soil test predictor of pasture production, for periods where soil moisture is non-limiting, is plant-available soil (Olsen) P. Strong correlation of Olsen P with measures of soil labile N obviously aid its predictive ability. The results indicate that the "quality" of soil N, and the rate at which this N is cycling in these systems may be increasing with increasing soil (P and S) fertility. P fertiliser applications to soils with Olsen P values above 40 µgP/g is inefficient in terms of pasture yield increases under the current environment, as the pastures are no longer P responsive.

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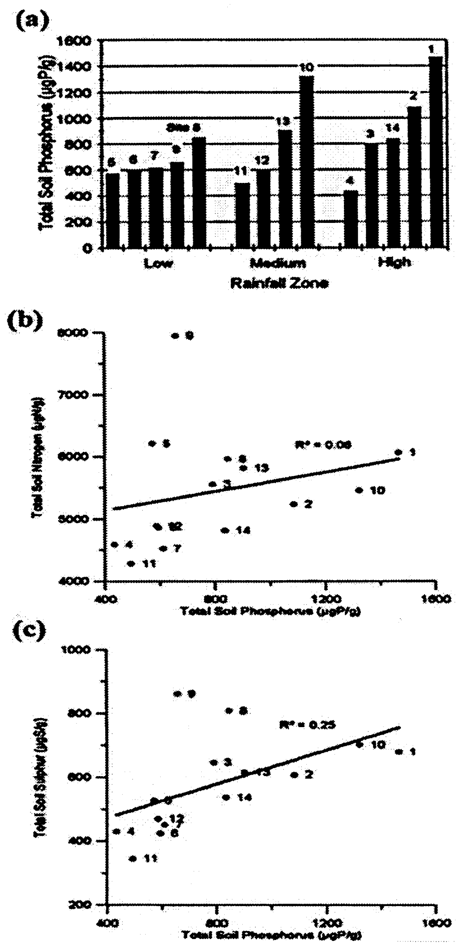

Figure 1
(a) Mean total soil P Content (0-75mm) at each site; (b) The relationship between total soil P and total soil N contents, and (c) The relationship between total soil P and total soil S contents.

Figure 2
(a) Cumulative annual pasture yield at selected high (H), medium (M) and low (L) fertility sites; (b) The relationship between Olsen P and pasture yield for a non-moisture limiting growth period (spring-early summer harvets), and (c). The relationships between Olsen P and; soil mineralisable (solid line, syandard text), and mineral N: total N ration (dashed line, bold italics).