Interactions Between the Effects of Nitrogen, and Phosphorus, Potassium and Sulphur on Grass Production

J. D. Morton
AgResearch, New Zealand

L. C. Smith
AgResearch, New Zealand

ID # 04-19

INTERACTIONS BETWEEN THE EFFECTS OF NITROGEN, AND PHOSPHORUS, POTASSIUM AND SULPHUR ON GRASS PRODUCTION

J. D. Morton and L. C. Smith

AgResearch, Invermay Agriculture Centre, PB 50034, Mosgiel, New Zealand

Abstract

The interactions between rates of nitrogen (N) and rates of phosphorus (P), potassium (K) or sulphur (S) on yield of ryegrass dominant swards were measured with no return of mown clippings in Southland, New Zealand. In the second year of the trial, the yield response to 176 kg N ha^{-1} compared with no N increased only slightly with increasing soil Olsen P from 8 to 91 μg g^{-1} soil. At 352 and 704 kg N ha^{-1} there was a large increase in the yield response (from 5 to 9.4 and 11 t DM ha^{-1} respectively) up to an Olsen P of 55 μg g^{-1} soil. At 176 kg N ha^{-1}, there was a linear yield response (from 3.5 to 6.5 t DM ha^{-1}) as ammonium acetate extracted soil K increased from 80 to 120 μg g^{-1} soil. A larger yield response to K (from 3.5 to 13.5 t DM ha^{-1}) was measured up to but not above 240 μg K g^{-1} soil at 352 and 704 kg N ha^{-1}. The yield response to 352 and 704 kg N ha^{-1} increased with soil S status (from 8.2 to 11.8 t DM ha^{-1}) up to 15 μg calcium phosphate extractable S g^{-1} soil. These results demonstrated that yield responses to increasing rates of N do not increase above a threshold level of other soil nutrients.

Keywords: Nitrogen, phosphorus, potassium, sulphur, grass, yield response

Introduction

N fertiliser is the main input of N on grass swards in most of the world's grazed pastures. Grasses also require lower rates of P, K and S fertiliser but where pastures are conserved with limited recycling of nutrients, nutrient inputs are much higher than under grazing. Most experiments that determine nutrient requirements do not supply information on how much of one nutrient should be applied in relation to others, so that pasture yield is optimised.

There was no interaction measured between N and P in ryegrass/clover yield by Reith *et al*. (1961), Paris and Paris (1985) and Mouat *et al*. (1987) in mowing trials with clippings removed. Reith *et al*. (1961) reported a N x K interaction on pasture yield. On an S responsive site, Walker and Adams (1958) could not measure a significant N x S interaction in total grass/legume yield under mowing.

Since the earlier field trials have been carried out without the soil nutrient data necessary to calibrate interactions in yield, further work was undertaken to provide this information for an all grass, pasture conservation system. A summary of the second year results is presented in this paper.

Material and Methods

Sites and soil

The trial was conducted at Woodlands near Invercargill, Southland, New Zealand on a Waikiwi brown soil under a cool temperate climate with mean annual rainfall of 1050mm. The establishment of ryegrass pasture was similar to the method described by Sinclair *et al*. (1996).

Design and treatments

The trial consisted of 4 rates of N by 4 rates of P, K or S in a complete factorial design in 3 replicate blocks. Trial plots were 4m x 1.5m. In the second year 0, 176, 352, and 704 kg N ha^{-1}

were applied in 10 split dressings after each cut. P was applied as mono calcium phosphate 3 times a year at rates of 0, 31.75, 62.5 and 125 kg P ha^{-1} $year^{-1}$. K was applied as potassium chloride (KCl) 4 times a year at rates of 104, 208 and 416 kg K $ha^{-1}year^{-1}$. S was applied as gypsum 3 times a year at 0, 31.25, 62.5 and 125 kg S $ha^{-1}year^{-1}$.

Measurements

Pasture production was mown to a height of 30 mm at 4-6 week intervals, or when yield was 1000 - 3000 kg DM ha^{-1}. All cut herbage was removed from the plots. Chemical extractants were sodium bicarbonate (30 minute Olsen), ammonium acetate and calcium phosphate for P, K and S respectively.

Statistical analysis

Data were analysed by analysis of variance with N and either P, K or S levels and their interaction as treatment factors and the replicates as a blocking factor. Curves were fitted using Mitscherlich equations.

Results and Discussion

Soil pH, P, K and S levels at the start of the trials were 5.46 and 7.5, 120 and 9.2 µg g^{-1}.

Interactions in yield response

N x P

At 176 kg N ha^{-1} there was no increase in DM yield response over control from Olsen P 8 to 91 µg g^{-1} (Figure 1). DM yield response increased up to Olsen P 22-33 µg g^{-1} at 352 and 704 kg N ha^{-1} ($P<0.10$) but this increase diminished at higher levels. The N x P interactions measured here contrast with the lack of interaction reported by Reith *et al.* (1961) and Paris and Paris (1985) but at both their sites, sufficient soil P was probably available over the duration of the trial to satisfy grass P requirements. Although Mouat *et al*. (1987) could not measure a N x P interaction at low soil Olsen P, this was attributed to an adequate supply of P from tribasic phosphates on a weathered alluvial soil. The results from our trial indicated that sufficient soil P was available to allow the grass to respond to a lower rate of N at nil P but that added fertiliser P, or higher soil P levels, was required to satisfy grass P demand at higher rates of N.

N x K

N x K interactions on yield (P<0.01) showed a similar pattern to N x P with only a small yield response at 176 kg N ha^{-1} as soil K increased from 80 to 380 μg g^{-1} but a steep linear response up to 120 μg K g^{-1} at 352 and 704 kg N ha^{-1}. Above 200 μg K g^{-1} the yield response levelled off. These results were similar to those reported by Reith *et al.* (1961) at K deficient sites. This result indicates that grass production at a lower rate of N does not require as much K as at a higher rate of N.

N x S

There was a significant negative effect of soil S (P<0.01) on yield response up to 176 kg N ha^{-1} (results not shown) which may have been due to competition between nitrate and sulphate ions for plant uptake. At 352 and 704 kg N ha^{-1}, there was a response up to about 15 μg S g^{-1} soil. Walker and Adams (1958) measured an interaction (non-significant) in grass yield between N and S, but recorded a negative effect of N on legume yield where S was applied resulting in a non significant N x S interaction in total yield.

Interactions between N and P, K or S on grass yields were greater at higher compared with lower rates of N. In the second year after grass establishment, soil Olsen P, ammonium acetate K and phosphate-soluble S levels of greater than 50 μg g^{-1}, 218 μg g^{-1} and 15 μg g^{-1} respectively were required to maximise the yield response to 352 kg N ha^{-1}. These critical soil values did not increase significantly at higher rates of N. Thus, soil testing is a valuable tool to define optimum soil P, K and S levels for grass production but soil P and K levels decrease at lower rates of N fertiliser.

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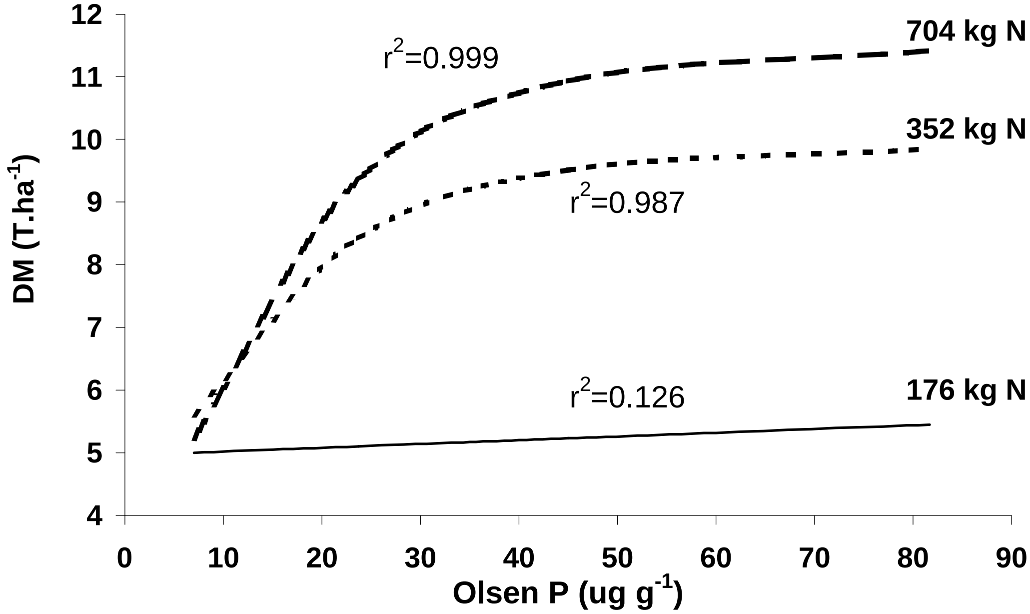

Figure 1 - Relationship between soil Olsen P nitrogen rates and dry matter yield of a ryegrass dominant sward

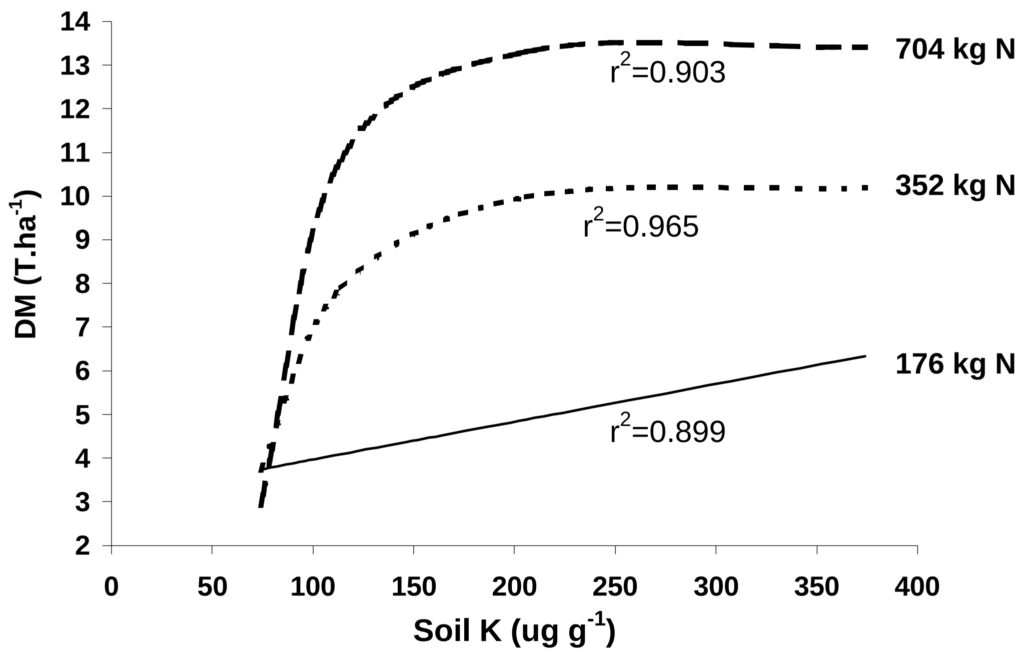

Figure 2 - Relationship between soil K nitrogen rates and dry matter yield of a ryegrass dominant sward.