Response of southern North Island hill pasture to nitrogen, molybdenum and lime

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Abstract

An experiment was designed to measure the effect of molybdenum (Mo), lime and nitrogen on steep (>30°) north-facing hill pasture on the Massey University Hill Farm, "Tuapaka". Treatments included application of molybdenum, lime (L), nitrogen (N) alone and together with Mo and lime. Mo and lime werre applied in mid May at 0.05 kg/ha and 2000 kg/ha separately, and N fertiliser was applied as urea in August and October at 60 and 20 kg N/ha respectively. Herbage and soil responses were measured over spring and summer 1992/93. Nitrogen fertiliser increased herbage mass accumulation from 3 to 41 kg DM/kg N applied, and the response was increased by the addition of lime or Mo. Ryegrass content increased in the sward and the low-fertility-tolerant grass species content decreased. Mo application increased the white clover content in the sward and subsequently resulted in the increase in herbage mass accumulation by 0.4% to 32%. The effect of Mo application was larger than that of liming but less than that of N alone application. Liming increased soil pH by 0.24-0.3 pH units per 2000 kg lime applied and soil moisture was increased from 2% to 26% over spring/summer, and the potential mineral nitrogen was increased by 94% in November. These resulted in the increase in herbage mass accumulation from 4.4% to 15%. These results indicate that Mo and lime applications would be beneficial on these hill soils.

Keywords: herbage mass accumulation, hill country, lime, molybdenum, nitrogen, *Trifolium repens*

Introduction

The key to pasture improvement in hill country is the introduction of high producing legumes after the correction of soil nutrient deficiencies (White 1990). The corrections of low soil pH and deficiency of molybdenum (Mo) are considered to be a very important steps for the establishment of improved pasture with high producing legumes in hill country (During 1972 1984; Edmeades 1984). It is generally agreed that Mo is critical for legumes and its application stimulates the legume growth and increases legume nitrogen (N) fixation (Scott 1963; During 1984). On the other hand, the use of lime has an effect on the physical properties of the hill soil as well as increasing soil pH and the availability of Mo (During 1962; Edmeades 1984). The steady input of N is necessary for maintaining more productive grass species in hill country as the spring flush of mineralised nitrogen is short-lived (Ball 1982; Luscombe 1979). The practical experience and research results suggested that an application of Mo, lime and a tactical application of is N a very effective way of increasing pasture productivity and improving soil properties in hill country in New Zealand when phosphorus (P) and sulphur (S) status is adequate (Edmeades 1984; During 1962, 1972, 1984; Luscombe 1979, 1981; Ball 1982). Information is available on the response of many hill soils to N (Luscombe 1979; Ball 1982), but there is a lack of quantitative information on the maintenance requirements for Mo and time for many hill soils and this makes it difficult to provide firm recommendations on their use. This paper reports some results from a field trial designed to examine the effects of lime, Mo and N on herbage production and soil characteristics in North Island hill country.

Materials and methods

Site

The experiment was located on a hill block of Tuapaka farm, Massey University, which lies south east of the Manawatu river extending up into the flanks of the Tararua range. The experimental site was on a hill sheep unit with a sunny north-west aspect and land slope of about 35-40°. A dry, warm summer and cool, wet spring is the main meteorological feature of this hill country. The soil is a Halcombe steepland soil which is associated with the yellow-grey earths (Pollock & McLaughlin 1986) with a soil pH range of about 5.2-5.4. The main pasture species on the hill country are the low-fertility-tolerant species, such as browntop *(Agrostis tenuis* Sibth.), chewings fescue *(Festuca rubra* L. *commutata* Gaud.) and sweet vernal *(Anthoxanthum odoratum).* Ryegrass (*Lolium perenne*

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L.) and white clover *(Trifolium repens* L.) occur in the pastures but are not abundant. No fertiliser has been applied in recent years on this hill country. The trial site was opened from mid May to October because the herbage growth was slow and animal grazing was not intensive. However, in late October it was electric fenced to exclude animals.

Experimental design and treatments

A randomised complete block design was used, associated with 4 replications of 6 treatments. Plot size was 3 m x 1.5 m. Six treatments were: (1) 0 - control, no fertiliser application; (2) N - nitrogen fertiliser applied in August (60 kg N/ha) and October (20 kg N/ha), 1992; (3) L - 2000 kg/ha time applied in mid May, 1992; (4) Mo - 50 g/ha molybdenum applied in mid May, 1992; (5) NMo - 50 g/ha Mo applied in mid May, N applied in mid August (60 kg/ha) and mid October (20 kg/ha), 1992; (6) NL - 2000 kg/ha lime applied in mid May, N applied in mid August (60 kg/ha) and mid October (20 kg/ha). Urea (46% N), sodium molybdate (39% Mo) and limestone (72% $CaCO_3$) were used separately as fertilisers. Nitrogen fertiliser and limestone were applied by hand broadcasting and sodium molybdate was dissolved in water and applied with hand spray.

Measurements

(a) Herbage mass

The accumulated herbage mass was measured monthly from mid September to January using electric shears to cut herbage to ground level within one randomly placed 0.25 x 0.25 m^2 quadrat per plot.

(b) Botanical composition

The botanical composition of all the plots was measured in July, November, December 1992 and January 1993 using a point quadrat. Only first needle contact was recorded as one point and 100 points were recorded on each plot. The percentage content of each species category was calculated based on its contribution to the total 100 points.

(c) Soil moisture (SM)

The soil moisture was measured monthly using Time Domain Refractometer (TDR) at a depth of 20 cm (before November) and 15 cm (December onwards).

(d) Soil pH

Soil samples from individual plots were taken on May, October at a depth of 7.5 cm. Soil samples were air dried and pH was measured in distilled water in 1:2.5 ratio (10 g soil:25 ml distilled water) using pH meter.

(e) Soil mineral nitrogen

Soils were sampled in November and a subsample was taken for aerobic incubation (for 14 days at 30°C). Incubated and unincubated air-dry soil samples were extracted with a 0.1M KC1 solution and analysed for nitrate (NO_3^-) and ammonium (NH,+) using an autoanalyser.

Statistical analysis

All data were initially analysed in accordance with the randomised complete block design of the experiment. The analysis of variance (ANOVA) of data and the tests for significance of differences among treatments used the Repeated Measures option of the General Linear Model procedure of PC-SAS. The chi-square test was used to examine the significance of N x L and N x Mo interaction.

Results and discussion

Response to N application

Nitrogen application significantly increased the herbage mass over spring/summer (Table 1). Table 2 shows that the N response efficiency (kg DM/kg N applied) varied from 3.5 to 41.4 kg DM/kg N applied under different treatments (N, NMo and NL treatments). Addition of Mo and lime increased the N response efficiency. The response between N and lime was additive and there was a significant N x L interaction whereas the response to N and Mo application was not

Table 1 Herbage mass over time for the fertiliser treatments (kg DM/ha).

Treatments	September	November	December	January
O	780 a	1074a	3435 a	**7169 a**
N	987 ab	1472 bc	4230 b	**9515 ab**
L	824 ab	1121 ab	3949 ab	7900 ab
Mo	989 ab	1413 abc	**3917 ab**	**7196 a**
NMo	978 ab	**1534 c**	4351 b	9963 ab
NL	**1147 b**	**1553 c**	5041 c	10481 b
SEM	107	120	197	237
F-test		NS	•	**

Note: means with the same letter within each column are not significantly different (P>0.05).
*: P<0.05 **: P<0.01 ● **: P<0.001 NS: not significant

Table 2 The N response efficiencies on applied N (kg DM/kg N applied).

Treatment	September	November	December	January
N	3.5	5.0	9.9	29.3
NMo	3.3	5.8	11.5	34.9
NL	6.1	6.0	20.1	41.4

Table 3 The seasonal botanical composition under different treatments (% content in the sward on each month)

Treatment	Ryegrass Jul	Ryegrass Nov	Ryegrass Dec	Ryegrass Jan	White clover Jul	White clover Nov	White clover Dec	White clover Jan	Browntop Jul	Browntop Nov	Browntop Dec	Browntop Jan	"Other grasses" Jul	"Other grasses" Nov	"Other grasses" Dec	"Other grasses" Jan
0	3a	lla	12a	13a	4a	12a	lla	Qa	26a	26b	19d	17c	36a	40b	42a	52a
N	19ab	26b	22b	23a	7ab	16ab	15ab	11ab	22a	19ab	12a	9ab	36a	35ab	40a	44a
L	15ab	21b	20b	19a	5a	19bc	16b	13ab	23a	23ab	18cd	12bc	41a	32a	36a	42a
Mo	17ab	21b	18ab	16a	5a	21c	18bc	16b	24a	16a	17cd	7a	40a	32a	36a	42a
NMo	17ab	25b	21b	20a	7ab	23c	21c	15b	22a	15a	13ab	14bc	45a	30a	35a	41a
NL	18ab	22b	23b	16b	Qb	20bc	16b	14b	20a	14a	15bc	10ab	43a	35ab	36a	47a
SEM	1.7	1.7	1.9	2.7	1.0	1.4	1.4	1.7	1.9	2.0	t.4	1.5	3.2	2.2	2.4	3.4
F-test	NS	• ✉	•	Ns	'	• ✉	**	✉•	✉•	• ✉	*	• ✉	NS	NS	NS	NS

Note: means with the same letter within each column are not significantly different (P>0.05).
*: P<0.05 **: P<0.01 ***: P<0.001 NS: not significant

additive and there was no interaction between them for increasing herbage mass accumulation. These were comparable with values reported by Luscombe (1979) of 10-25, Sherlock & O'Connor (1974) of 24, and Ball *et al.* (1976) of 14-3 1 kg DM/kg N applied. The seasonal differences of N response efficiency is most likely to be attributable to the variable weather over spring/ summer. Pasture growth was good in summer, requiring more available N, and resulted in a larger N response efficiency (Table 2). This is in agreement with the suggestion by Ball (1978) that the requirements for N at high growth rates were proportionately greater than at low growth rates.

The N application increased the ryegrass content in the sward but the white clover content was little affected (Table 3). In addition, the fact that the N application decreased the browntop and other low-fertility-tolerant grasses species content in this hill pasture, suggests that pasture species may be critical in determining N responses in lower fertility pastures. This was supported by some early reports (Luscombe et *al.* 1981; Ball et *al.* 1982).

Response to Mo application

Mo application increased herbage mass on average by 18% during the period from September to January compared with control treatment (Table 1) but the effect tended to decrease over spring/summer. The effect of Mo application was equivalent to the N treatment in spring but declined over summer. Mo increased both the white clover and ryegrass content in the hill sward at the expense of browntop (Table 3). These responses can be explained by a 17% increase in available soil N and a 25% increase in potential mineralisable N compared with control (Table 4). Mo deficiency can often be alleviated by liming but the response to lime followed a different pattern to the Mo response, suggesting that this was not the case.

Table 4 The soil nitrogen status of existing mineral N (EMN) and potentially mineralisable N (PMN) in October (µg N/g soil within 0-7.5 cm soil depth).

Treatments	EMN	PMN
0	0.870 a	1.325 a
N	1.136 a	1.250 a
L	1.120 ab	2.263 c
fib	1.015 ab	1.653 ab
NMo	1.320 b	1.338 a
NL	1.263 ab	2.133 bc
SEM	0.122	0.177
F-test	Ns	*

Response to liming

Lime application significantly increased herbage mass from 4% to 15% compared with control (P>0.05) and the response increased over spring/summer (Table 1). However, the effect of liming was from 7-24% less than that of N application. The response to lime was less than that to Mo over spring, but subsequently it was larger than the Mo response. Lime application increased the white clover content (from 25% to 58% compared with control) (Table 3), probably owing to the increase in soil pH and possibly Mo availability in this hill soil. Liming also increased the rate of soil N mineralisation; available mineral N was 29% and potential mineralisable N 71%-greater than the control (Table 4). Edmeades *et al.* (1990) found that the major effect of liming was initially to enhance grass production, presumably by increasing the rate of net soil N mineralisation. On the other hand, liming increased soil moisture by 1.526.3% compared with control (Table 5), which was attributed to the effect of liming on the hill soil structure improvement. This could account for the positive response of herbage mass accumulation to lime application in summer. Jackson & Gillingham (1985) suggested that lime improved soil moisture relationships by alleviating water repellency of hill soils.

Table **5** The monthly soil moisture on different treatments (% by volume)

Treatments	AUG	SEP	NOV	DEC	JAN	MEAN
0	33.7 ab	33.2 ab	21.8 ab	21.3 a	21.5 a	26.3 a
N	29.3 a	31.0 a	19.1 a	22.4 a	21.6 a	24.7 a
L	34.2 ab	34.0 ab	27.0 b	26.9 b	23.9 ab	29.2 ab
Mo	31.7 ab	31.9 a	23.6 ab	23.3 a	22.1 ab	26.5 a
NMo	30.7 a	30.9 a	21.6 ab	21.7 a	22.6 ab	25.5 a
N	36.6 b	36.7 b	23.6 ab	27.5 b	25.2 b	30.0 b
SEM	1.7	1.4	2.2	1.3	1.5	0.6
F-test	NS	NS	NS	•	NS	NS

Note; means with the same letter within each column are not significantly differ ($P>0.05$);
*: $P<0.05$ **: P<0 01 ● *: $P<0.001$ NS: not significant

Conclusions

1. The applications of Mo, lime and N were very effective in this hill pasture owing to the low soil N availability and Mo deficiency.
2. Mo application increased herbage mass from 0.4% to 32% and the effect tended to decrease over the spring/summer. The effect of Mo application was larger than that of liming but less than that of N alone application. An increase in white clover content in the sward was considered to be the main reason for this response. Mo application has great economic potential for hill farming practice.
3. Liming significantly increased the soil pH from 0.24 to 0.3 units/2000 kg lime applied and the soil potential mineralisable N increased by 71%. Also, liming increased the soil moisture over dry spring/summer from 11% to 26%. The result was an increase in herbage mass accumulation from 4.4% to 15%.
4. N fertiliser increased herbage mass by from 3 to 41 kg DM/kg N applied, and the response was increased by the addition of lime or Mo.

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