Proceedings of the New Zealand Grassland Association 50: 243-247 (7989)

WHAT IS THE MAXIMUM PRODUCTION ON OTAGO HILL COUNTRY ABOVE 700 METRES ALTITUDE?

P.D. McIntosh' and J.F. Wales[2]
'Division of Land and Soil Sciences, DSIR, Dunedin
[2]Divison of Land and Soil Sciences, DSIR, Lower Hutt

Abstract

To ascertain the maximum production of grass/clover pastures over a range of altitudes on Otago hill country, and the increase obtainable by applying nitrogen (N). 4 trials were set up at intervals from 730 m to 1190 m altitude, on yellow-brown earth soils of the Dunstan set on Loch Linhe station, overlooking Lake Wakatipu. The trials were oversown with a grass/clover mixture. The effects of fertilising with adequate phosphate(P) and sulphur (S), with and without lime, and with and without N, was investigated. Yields were compared with those at other sites in Otago at similar altitudes

Responses to P and S only were noted in year 1 and no altitude-related trend was evident Production in years 2 and 3 however showed a clear altitude-related trend. Without N maximum production ranged from 6390 kg/ha at 730 m to 1690 kg/ha at 1190 m. Yields with N were 8130 kg/ha at 730 m and 4150 kg/ha at 1190 m, i.e N increased yields by 27% to 146%; the greatest percentage increase was at highest altitude. Maximum production decreased by about 865 kg/ha per 100 m of altitude increase

Lime depressed yields at the lower altitude sites and raised yields at the higher altitude sites, but only at the most acid site (topsoil pH 4.9) with **N was the yield difference due to lime** statistically significant.

Yields of clover/grass pastures obtainable with adequate P and S fertiliser, without added lime, are greater than at sites of comparable altitude in east and north Otago. Soil temperature measurements indicate that higher temperatures are the likely cause of the higher production Areas of favourable climate and soils, such as the one studied, will probably give the greatest return on investment in fertiliser. Climatic maps of hill country are needed to help predict production potential.

Keywords: hill country, Otago, fertiliser. pasture yields, yellow-brown earths

INTRODUCTION

Upland and high country yellow-brown earths cover about 1.7 million hectares of Southland and Otago (NZ Soil Bureau 1968). Many of the lower altitude soils such as the Waipori and Wehenga soils around Dunedin have been developed for pastoral agriculture and their fertiliser requirements and production potential have been established through a combination of farmer experience and field trials (e.g. Cossens & Radcliffe 1978). The potential production and fertiliser requirements of the high altitude soils are less well known and have been systematically evaluated only at a few locations: for example, on the east Otago uplands by Cossens & Brash (198 1) and McIntosh et a/. (1984); near Lake Wakatipu by Floate et *al.* (1985): and in North Otago by McIntosh *et a/.* (1985).

Maximum annual production of legume/grass pastures at comparable altitudes over 1000 m was 2500 kg/ha or less in North Otago and on the east Otago uplands, but was 3000 to 4000 kg/ha near Lake Wakatipu. Floate et *al.* (1985) suggested that superior yields near Lake Wakatipu might be caused by a warmer and longer growing season than that of the east Otago uplands.

This study was performed to confirm the production potential of soils of the Dunstan set under different fertiliser treatments, and to relate production to soil

temperature. The conclusions of the study apply not only to soils of the Dunstan set (340 000 ha) but also to similar areas of the schist high country (soils of the Fairlight, Moonlight and Waikaia sets) covering 295 000 ha.

SITE CHARACTERISTICS

Soils were described at sites at 730 m, 870 m, 1020 m and 1 190 m altitude on Loch Linhe Station, Lake Wakatipu. The sites were named A to D respectively. All sites were on hill slopes of 20' to 24" and had a westerly aspect. Soils at all sites were mapped in the Dunstan set by NZ Soil Bureau (1968) but were identified as Tawhite silt loam, an upland yellow-brown earth (Leamy 1971) at sites A and B, and Teviot stony silt loam, a high country yellow-brown earth (Leamy 1971) at sites C and D. Site characteristics are listed in Table 1. Site A had been previously topdressed with superphosphate. No lime had been applied to any site. Soil 'Quick-test' results indicated that major nutrients (K, Mg) not added in fertiliser in the experiment were adequate for pasture growth.

METHODS

Trials consisted of 5 treatments in 3 replicates:

1. Control.
2. 40 kg P/ha and 50 kg S/ha annually.
3. P and S as in treatment 2 plus 4 t lime/ha (initially).
4. P and S as in treatment 2 plus 300 kg N/ha annually.
5. P and S and N as in treatment 4 plus 4 t lime/ha (initially).

A basal dressing of sodium molybdate at 200 g/ha was applied to all plots. P was applied as monocalcium phosphate, S as gypsum and N as urea. P and S were applied in spring. N was applied as 3 split dressings of 100 kg/ha each, in spring, summer and autumn. Topsoils (O-7.5 cm) were sampled each spring to monitor pH, the final sampling being in October 1987. Where pH of limed treatments (Treatments 3 and 5) fell below 5.8, lime was applied to maintain pH of individual plots at 5.8 or higher.

Plots were 1 m x 3 m, arranged along the contour, with 0.5 m buffer strips between plots. The plots were sown in October 1983 with a mixture of 3 kg/ha 'Grasslands Huia' white clover (*Trifolium repens* L.), 3 kg/ha 'Grasslands Pawera' red clover (*T. pratense* L.), 3 kg/ha alsike clover (*T. hybridum* L.), 9 kg/ha 'Grasslands Apanui' cocksfoot (*Dactylis glomerata* L.), 12 kg/ha 'Grasslands Ruanui' ryegrass (*Lolium perenne* L.), and 1 kg/ha crested dogstail (*Cynosurus cristatus* L.). Plots were fenced from grazing by sheep, cattle and rabbits. Clover seeds were inoculated with the appropriate *Rhizobium* at 5 times the recommended rate and coated with lime at a 1 :1 seed:lime ratio. The trials were cut 2 or 3 times annually with a 'Tas' disc mower, to within about 3 cm of the ground surface. Clippings were discarded. No attempt was made to measure or correct any moisture limitations for plant growth.

Rainfall, minimum air temperature and soil temperature at 50 cm depth were recorded monthly from June 1984 to May 1987 (Table 1). Mean annual soil temperature was calculated from a plot of monthly measurements.

RESULTS

Trials were not cut in the establishment year (1983/84) as there was little observable production from sown grasses and clovers. Results for 1984/85 (year 1) and subsequent years (years 2 and 3) are shown in Fig. 1.

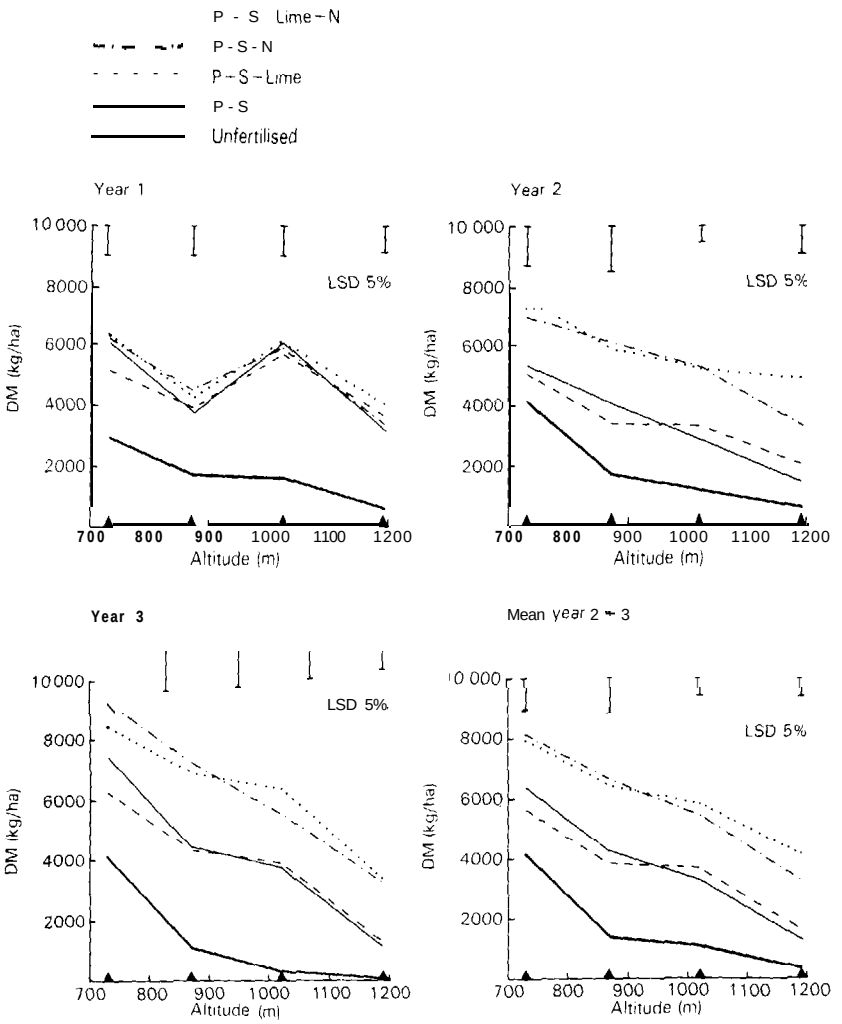

Figure 1: Herbage yields at the 4 trial Sites.

Year 1 results differ from those obtained in years 2 and 3 in that there was no altitude-related trend and no response to N. In years 2 and 3 there was a strong response to N and a strong altitude-related trend. Mean production of these two years has therefore been presented. Mean annual production without N ranged from 6400 kg/ha at site A to 1690 kg/ha at site D. In years 2 and 3 the response to N was significant at all sites and ranged from a 27% increase in yield at the lowest altitude site to a 146% increase at the highest altitude site. Lime depressed mean yields at sites A and B and raised mean yields at sites C and D, both with and without N. However the only significant ($P<0.05$) effect of lime was the increase in production with lime in the presence of N at site D in year 2.

Application of lime at 4 t/ha in spring 1983 was sufficient to maintain topsoil pH

at 5.8 or higher until spring 1986 on sites A to C; the increase in pH per tonne of lime was 0.10 unit at site A, 0.13 unit at site B and 0.15 unit at site C. By October 1987, topsoil pH on limed treatments declined by 0.2 unit i.e., the effect of 4 t lime/ha lasted 3 years and declined during the fourth. Trial D required additional lime to maintain pH levels at 5.8 or higher, A total of 7.33 t lime/ha was applied. This raised topsoil pH by 0.16 unit per tonne of lime by October 1987.

Application of N without lime significantly depressed topsoil pH by 0.55 and 0.45 units (compared with controls) at sites A and B respectively. The pH depression due to N decreased with increasing altitude, was not significant ($P<0.05$) at site C, and did not occur on trial D at highest altitude. On limed treatments N did not depress topsoil pH.

DISCUSSION AND CONCLUSIONS

The results confirm the observation of Floate et al. (1985) that, with P and S fertiliser, yields of about 2000 kg/ha to 6000 kg/ha can be obtained from clover/grass pastures on soils of the Dunstan set at 700 m to 1200 m altitude near Lake Wakatipu. These yields are superior to those obtained at similar altitudes on the east Otago uplands (McIntosh et *al.* 1984) and at most sites in North Otago (McIntosh et al. 1985).

The mean annual soil temperature at 1020 m, adjusted for deviation from the long term mean, was 7.0°C (Table 1). this temperature is equivalent to a mean annual air temperature of 6.1 °C (Thomas et al. 1980) which is 1 .1 °C higher than that recorded by Otago University at 1000 m altitude on the east Otago uplands over the period 1967 to 1977 (Cossens & Radcliffe 1978). The lapse rate over the altitude range of the trials is 0.3°C per 100 m, half the average for New Zealand (Taylor & Pohlen 1979) or Southland (Sansom 1984). These figures confirm that soils of the

Table 1: Site characteristics

Soils' (0-7.5 cm)

Site	Altitude (m)	pH	MAF Quick tests Olsen P (µg/g)	Ca	Mg	K	SO_4-S (µg/g)	Phosphate retention (%)
A	730	5.6	20	6	21	10	7	18
B	870	52	10	3	17	9	4	41
C	1020	5.3	7	2	12	7	4	47
D	1190	4.9	32	2	9	5	3	40

Climate[2]

Site	Altitude (m)	Mean annual soil temperature (50 cm) (°C)	Adjusted mean annual soil temperature (C)	Minimum air temperature[3] (°C)	Mean annual rainfall[4] (mm)
A	730	8.5	7.8	-6.3	670
B	870	8 2	7.5	-7.8	720
C	1020	7.7	7.0	-9.3	710
D	1190	7.1	6.4	-9.0	740

[1] Mean of 15 samples taken before fertiliser application.
[2] June 1984 to May 1987 inclusive. Adjusted temperatures are corrected from the deviation of Queenstown air temperatures from the long-term Queenstown mean during this period.
[3] Recorded in September 1984.
[4] Minimum values. As rainfall was recorded monthly from storage ram gauges, evaporation losses will have occurred.

Dunstan set in the Lake Wakatipu area have a warmer climate than upland and high country soils of comparable altitude elsewhere in Otago. Aspect, high sunshine hours and shelter from prevailing winds probably contribute to the favourable temperatures. The figures emphasise the need for taking climate as well as soil factors into account when developing upland and high country soils into improved pasture.

The yields obtained with N ranged from 8130 kg/ha at 730 m to 4150 kg/ha at 1190 m, i.e., maximum yields decreased by about 865 kg/ha for each 100 m increase in altitude. Maximum yield at 730 m altitude was about half that obtained by Risk (1982) at Woodlands, at 47 m altitude. The percentage increase in yield obtained with N at 730 m (27%) was lower than that obtained by Risk (34%).

The increase in yields obtained with N were expected as N is deficient in all natural and sown grasslands. The increase in N response with increasing altitude is probably a result of less N fixation by clovers in the cooler, higher altitude soils (Hoglund et al. 1979). The decreasing depression of pH by N application with increasing altitude leads us to conclude that pH decline is due to pasture growth rather than a direct effect of urea application.

If economic conditions at some time favour N application to soils such as these, the pH decline caused by N application should be monitored and if necessary corrected by lime application.

The lack of significant ($P<0.05$) response by pastures to lime (without N) indicates that lime is not required during the initial stages of pasture development on these soils.

The observation that these soils produce about double the pasture yield of soils at comparable altitude on the east Otago uplands, without the necessity for lime application, stresses the need for further evaluation of soils of the extensive Dunstan set and similar soils, and the need for climatic as well as soil mapping before investment decisions are made.

Acknowledgements

To Mr Murray Scott of Loch Linhe Station for *allowing* **trials to be set up: lo Dr J. Reynolds for statistical analyses; to Ms M. Casey and Mr C. Smith (MAF) for assistance during fieldwork.**

References

Cossens **G.G.; Brash D.W. 1981. Seasonal distribution of pasture production in New Zealand XV. The higher Otago plateau. Rock and Pillar Range. NZ** *journal of expenmentat agriculture 9.* **73-78.**

Cossens G.G.; Radcliffe J.E. 1978. Seasonal distribution of pasture production in New Zealand XIV The lower Otago plateau: Hindon. NZ journal of experimental agriculture 3: 127-33.

Floate, M.J.S.; McIntosh. P.D.. Risk W.H.; Enright, P.D.; Smith, L.D. 1985. Effects of fertilisers and environment on lotus production *on* **high** *country* **acid soils in** *Otago. Proceedings NZ Grassland Association 46.* **1 11-1 8.**

Hoglund, J.H.; Crush, J.R.; Brock, J.L.; Ball, R. 1979. Nitrogen fixation in pasture XII. *General* **discussion. NZ** *journal of expenmentat agriculture 7:* **45-51.**

Leamy, M.L. 1971. Some characteristics of the upland and high country yellow-brown earths NZ journal of *science 14:* **1057-81.**

McIntosh. P.D.; Enright, P.D. Sinclair A.G. 1984. Fertilisers for lotus and clover establishment on a sequence of acid soils on the east Otago uplands. NZ journal ot expenmentat *agriculture 12:* **119-29.**

McIntosh, P.D.; Sinclair, A.G.; Enright P.D. 1985. Responses of legumes to phosphorus and sulphur fertilisers on two toposequences of North Otago soils, New Zealand NZ journal of agricultural research 28: 505-l 5.

NZ Soil Bureau 1968. Soils of South Island, New Zealand. NZ *Soil* **Bureau** *Bulletin* **27.**

Risk, W.H. 1982. The use of nitrogen fertiliser on the Southland Plains. p. 149-58. In Lynch, PD. (Ed) Nitrogen fertilisers in NZ agriculture Wellington: NZ Institute of Agricultural Science.

Sansom, J. 1984. The climate and weather of Southland. *NZ Meteorological Service Miscellaneous Publication 115(15).*

Taylor, N.H.; Pohlen, I.J. 1979. Soil Survey Method. NZ *Soil* **Bureau** *Bulletin* **25**

Thomas, RF.; Blakemore. L.C.; Kinloch, D.I 1980. Flow diagram keys for "Soil Taxonomy". B Soil moisture and temperature regimes, *and* **diagnostic horizons and properties for organic soils. NZ** *Sort Bureau Scientific Report 398.*