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EFFECTS OF **FERTILISERS** AND ENVIRONMENT ON LOTUS PRODUCTION ON HIGH COUNTRY ACID SOILS IN OTAGO

M.J.S. FLOATE, P.D. McINTOSH, W.H. RISK, P.D. ENRIGHT and L.C. SMITH
Research Division, MA F,
Invermay Agricultural Research Centre, Mosgiel

Abstract

To test the performance and nutrient requirements of Grasslands Maku lotus (Lotus *pedunculatus)* on high country acid soils under tussock grassland, the effects of phosphorus (P), sulphur (S) and lime on lotus and clover yields were measured in cut plots on sites ranging in altitude from 700 from 1200 m on the Remarkables Range (topsoil pH 5.5 - 4.8), and on the East Otago (Lammerlaw-Lammermoor) uplands (topsoil pH 5.2 - 4.4).

On the Remarkables, mean annual yields for P + S treatments decreased from about 7000 to 3500 kg DM/ha and on the Lammerlaw-Lammermoor sequence the decrease over the same altitude range was from about 2000 to 200 kg DM/ha.

Soil test values for S and P were low at all Lammerlaw-Lammermoor sites: S-deficiency was so severe that there was very little response to P until S was added and in most cases there was little response to S in the absence of P.

On the Remarkables soil test values were more variable and lotus yields were closely related to soil test values.

Fertiliser requirements of lotus were generally similar to those of clover, but clover occasionally continued to respond to higher rates of P than lotus. In contrast to clover, lotus showed little or no response to lime, except at the highest altitude (i.e. lowest pH) on the Lammerlaws.

In both Remarkables and Lammerlaw-Lammermoor sequences lotus and clover yields were similar up to 1000 m but above this altitude lotus production exceeded clover on the Remarkables. On the Lammerlaws yields dropped off sharply at the highest altitude but clover yields where lime was applied were significantly higher than lotus.

Decreasing lotus yield with increasing altitude is attributed to increasing severity of climate (probably low temperatures). The lower yields and greater decrease on the Lammerlaws suggest that the limitations are more severe there than at corresponding altitudes on the Remarkables.

Keywords: Lotus, high country, fertiliser, lime, climate

INTRODUCTION

The distribution of *Lotus pedunculatus (“Lotus major”)* ecotypes on wet acid soils in parts of lowland New Zealand suggested that is could be suitable legume for pasture development in places unfavourable for clover (Levy 1951). One of the earliest references to the use of lotus in such conditions was the work of During *et al.* (1964) who considered that *L. penduncula*tus might be a better pasture legume for Pakihi (gley podzol) soils than clover. They showed that on these very acid (pH 4.4 -4.5) soils clover needed at least 3.75 tonne/ha lime while lotus grew satisfactorily with less than half as much: there was less difference between the legume species in their initial requirements for phosphorus (P) fertiliser.

Subsequently, the lower lime requirement, and more satisfactorily growth of *Lotus pedunculatus* on acid soils have been demonstrated by Greenwood (1961), Scott et al. (1974), Nordmeyer & Davies (1977), Lowther (1977) and Morton (1981), but the early work did not investigate the needs of lotus for sulphur (S) and there is some doubt about the relative fertiliser needs of lotus and clover. Brock (1973) for example, found that with low P input lotus growth and P uptake were significantly greater than those of white clover, but with high P input clover production exceeded that of lotus. This reversal of relative yields with changing P-status raises questions as to the best choice of legume for pasture development.

Because of the proven acid tolerance of Lotus *pedunculatus* it was considered as a likely legume for pasture development on high country acid tussock grassland soils in Otago where lime costs to render the soil suitable for clover-based pastures might be prohibitive. There is however, no information on the relative performance of lotus and clover under these harsh climatic conditions where the growing season is short. Accordingly, trials have been conducted to compare the performance of clover and lotus over the elevation range 700-1200 m at 2 high country locations in Otago. At both sites the requirements for lime, P and S of both pasture species have been investigated. Results for the first 3 years of the Lammerlaw-Lammermoor trials have been reported by McIntosh et *al.* (1984) and in this paper we have collated the main findings on lotus production from both series of trials.

MATERIALS AND METHODS

Following a topsoil survey of the Otago Uplands (McIntosh & Backholm 1981) 5 trial sites were chosen on the Lammerlaw-Lammermoor Ranges to represent the range of soil properties which were related to increasing altitude and rainfall. Detailed site descriptions were give? by McIntosh et *al.* (1983) and are summarised in Table 1. Soils were yellow-brown earths of the Teviot set and a podzolised yellow-brown earth, and all sites were situated on rolling slopes with N aspect. Native vegetation was dominated by snow tussock (Chionochloa *rigida*) except at the lowest altitude site where red tussock, (*Chionochloa rubra*) was dominant.

Table 1: SITE AND SOIL CHARACTERISTICS OF 2 SEQUENCES OF TRIAL SITES ON THE LAMMERLAW-LAMMERMOORS AND THE REMARKABLES.

Location	Altitude (m)	Slope (degrees)	Rainfall (mm)	Temperature[1] (°C)	Growing[2] season (days>5 °C)	pH	Olsen-P (ug/g)	SO_4-S (ug/g)
Lammerlaws								
1	1160	8	1100	6.1	210	4.4	7	7
2	1100	10	1000	6.4	221	4.6	3	5
3	1040	4	755	6.7	231	4.6	7	6
4	855	6	630	7.6	263	4.8	10	6
6	760	9	470	8.0	280	5.2	8	3
Remarkables								
7	1190	22	(3)	6.2	214	4.8	40	3
8	1060	23		6.8	227	5.1	4	7
9	870	22		7.7	246	5.3	14’	10’
10	730	18		8.3	261	5.5	22[4]	11[4]

[1] Mean annual soil temperature at 30 cm depth, calculated from formula using latitude and altitude Thomas et *al.* (1980).
[2] Numbers of days when mean temperature >5 °C using data for Rock and Pillar (NE aspect) as an approximation for Lammerlaws (Meurk, 1982).
[3] Rainfall on this sequence is not known, but mean annual rainfall at 338 m at Frankton (20 km N) and at 313 m at Kingston (15 km S) are 750 and 948 mm respectively.
[4] May have been affected by drift from aerial topdressing.

A second sequence of 4 sites, between 730 and 1190 m a.s.l. was chosen on the W facing hilly slopes of the Remarkables Range. The soils on this sequence were yellow-brown earths of the Dunstan set and soils at corresponding altitudes were less acid than on the Lammerlaw-Lammermoors (Table 1). Vegetation was dominantly snow tussock at the 3 highest sites and hard tussock (*Festuca* novae *zelandiae*) at the lowest altitude.

At all these sites similar lime x P x S trial designs were used to establish (a) a mixture of red and white clover, and (b) Grassland Maku lotus in 1979-80 on the Lammerlaw-Lammermoors and in 1980-1981 on the Remarkables. Details of treatments, seed rates and fertiliser materials are given in Table 2.

Table 2: FIELD TREATMENTS EMPLOYED IN 2 SEQUENCES OF TRIALS ON THE REMARKABLES AND LAMMERLAW-LAMMERMOORS.

	Remarkables	Lammerlaws
Lime rate	0, 2500 kg/ha in year 1	0, 4000 kg/ha in year 1
P rate	0, 15, 30, 60 kg P/ha as monocalcium phosphate in 1980 and annually since 1982	0, 20, 40, 80 kg P/ha as monocalcium phosphate in year 1, half quantities annually thereafter.
S rate	0, 12.5, 25, 50 kg S/ha annually as gypsum	0, 50 kg S/ha annually as gypsum
Clovers	3 kg/ha Grassland Huia + 3 kg/ha Grassland Pawera	
Lotus	12 kg/ha Grassland Maku (Lotus *pedunculatus*)	
Inoculum	Clover : Rhizocotelgum arabic at 5 x recommended rate	Clover : Rhizocotelgum arabic at 5 x recommended rate and coated with lime
	Lotus : Inoculated but not lime coated.	
Sowing dates	1980 Nov-Dee	1979

Legume production assessment in the first year was by visual scoring only, and visual scoring was also used on the Remarkables sites in year 2. In all other years legume herbage has been cut using a Tas mower and legume dry matter (DM) production recorded after dissection of herbage samples. Data presented are for total legume yield from 1, 2 or 3 cuts in each year. In general only one cut (January or February) has been taken from the highest sites while multiple cuts (December-April) have been possible on the lower sites.

RESULTS

Mean annual lotus yields for 1980-84 (Lammerlaw-Lammermoor) and for 1982-84 (Remarkables) are presented in Figure 1. The data for all P + S fertiliser treatments indicate potential production, while the data for control, P- and S- only treatments indicate the severity of nutrient deficiencies.

Yields for P + S treatments on the Lammerlaw-Lammermoor sequence averaged over the period 1980-84 were low and declined from just less than 2000 kg/ha DM at 760 m to about 1000 kg/ha at about 1000 m a.s.l. Above this altitude lotus yields fell sharply to negligible amounts at 1160 m, where in 2 of the 4 years there was not sufficient herbage to cut either because of the short growing season or frost damage. On the Remarkables yields of lotus were much higher; the corresponding yields for all P + S treatments exceeded 6000 kg/ha at 730 m and decreased to within the range 3000-4000 kg/ha above 1100 m.

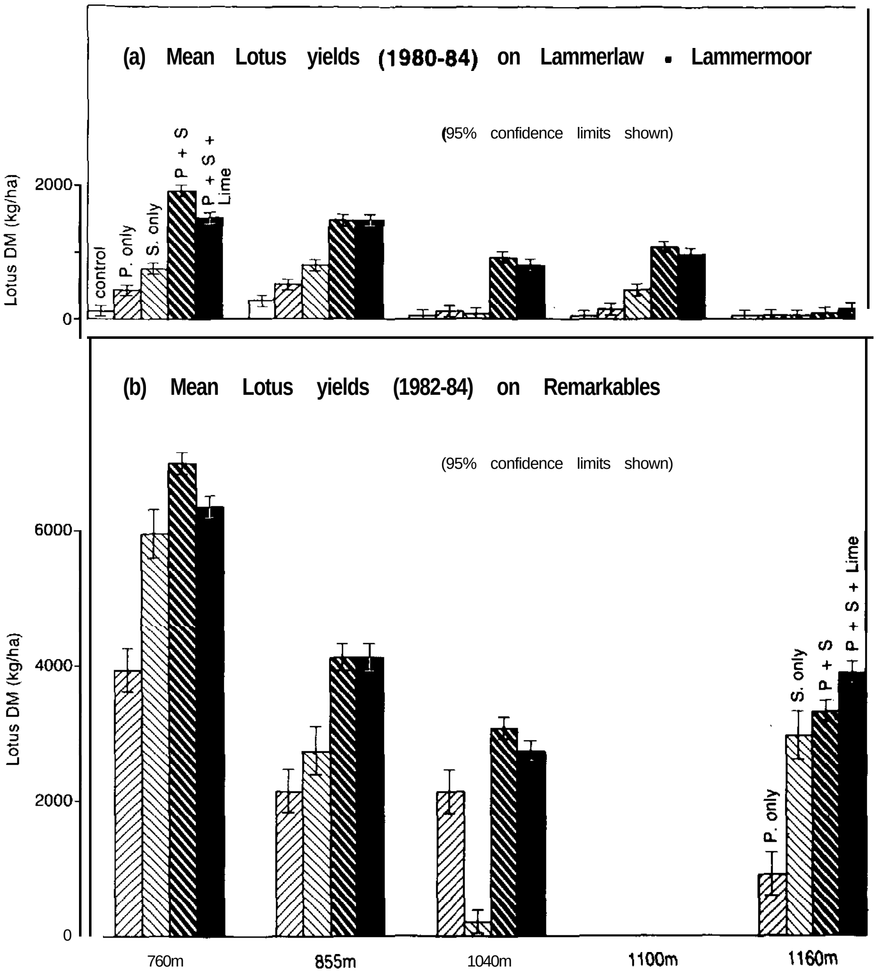

Figure 1: The effects of fertiliser treafments and altitude on mean annual yields of lotus on (a) lammerlaw-lammermoor ranges (1980-84) (b) Remarkables range (1982-84).

Lotus yields in the absence of any added fertiliser were very low at all sites on the Lammerlaw-Lammermoors (Fig. la). When P was applied alone yields were in most cases almost as small and soil tests show that this was because production was limited by severe S deficiency (Table 1). Similarly, at the 3 highest sites, when only S was applied, lotus yields were limited by severe P deficiency as indicated by low Olsen-P soil test values (Table 1). A related, but less marked effect was observed at the 2 lower sites where P status was marginally higher. It is important to note that maximum yields were only achieved when both P and S fertilisers were applied together.

Lotus production on the Remarkables (Fig. lb) was also closely related to soil test results. At the 2 lower sites where P and S levels were moderate and possibly affected by drift from aerial topdressing, lotus yields were in the range 2000-4000 kg DM/ha when P only was applied and up to 6000 kg/ha when S only was applied at the lowest site. At the 2 highest sites the very low lotus yields with S alone at 1060 m, and with P alone at 1190 m were due to severe deficiencies of the other major nutrient at each site. There was no significant yield increase due to lime.

Yield data for lotus production with increasing amounts of P indicate that with few exceptions, at least 60% maximum yield was achieved with the smallest rates of applied P. These smallest rates were an initial application of 20 kg/ha in the first year followed by 10 kg/ha annually on the Lammerlaws, and 15 kg P/ha in 1980 and annually since 1982 on the Remarkables. Data presented by McIntosh et *al.* (1984) for earlier years on the Lammerlaw-Lammermoor sequence led to similar conclusions.

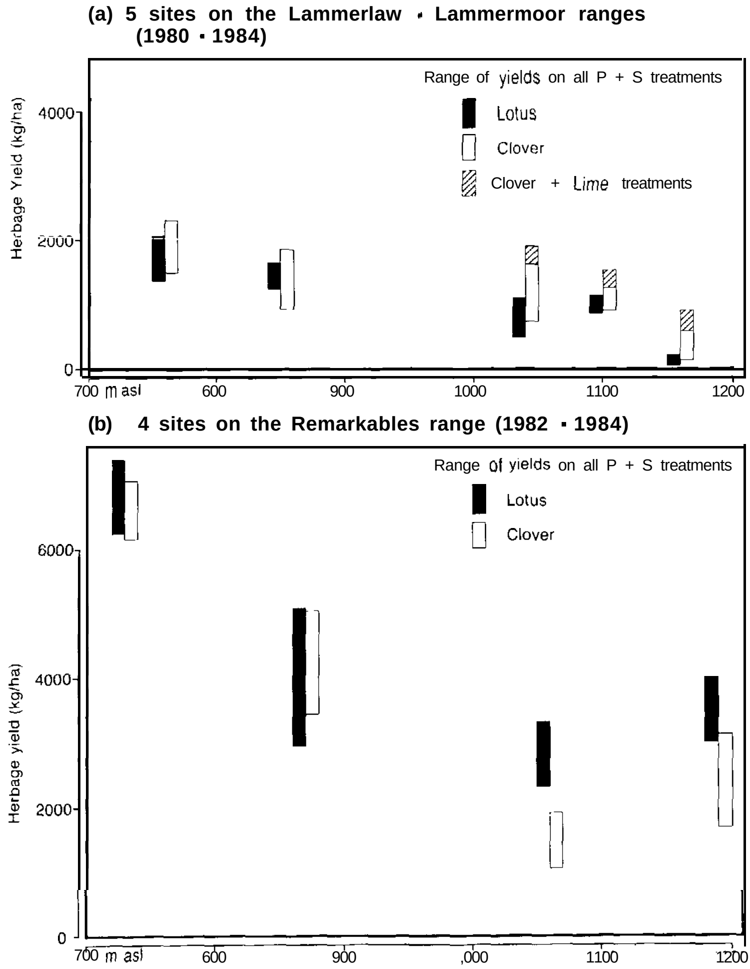

Figure 2: Annual yield ranges of lotus and c/over for all P + S treatments at **(a) 5 sites** *on the Lammerlaw-Lammermoor ranges (1980-84) and (b) 4 sites on the Remarkables range (1982-84).*

On the Lammerlaw-Lammermoor sequence only one application rate of S (50 kg/ha as gypsum) was used and this was always sufficient for optimum production but on the Remarkables lower rates were also applied. With these lower rates yields were almost as high as at the highest rate and 12.5 kg/ha S gave at least 75% of maximum yield.

The yields of lotus compared with clover at each site in the 2 sequences are illustrated in Figures 2a and 2b. At both lower sites on the Lammerlaw-Lammermoor sequence and on the Remarkables (below 1000 m) there was no significant difference in average yield between the two species. Above 1000 m lotus produced significantly higher yields on the Remarkables while clover produced significantly more than lotus at the 3 highest sites on the Lammerlaws. This latter difference was significantly enhanced by the application of lime. These results are somewhat different from those for the earlier years on the Lammerlaw-Lammermoor sequence (McIntosh et *al.,* 1984) for reasons which will be discussed below.

DISCUSSION AND CONCLUSIONS

The early faith of Levy (1951), During et *al.* (1964) in *L. pedunculatus,* then known as Lotus *major,* as a legume for acid and infertile soils, and the subsequent development and selection of Grasslands Maku (Barclay, 1957, 1960; Barclay & Lambert, 1970) has been justified by its success as a pioneer legume on infertile North Island hill country, in revegetation of eroded soils, and on some acid infertile tussock grasslands in the South Island. However, one of the stated aims of the development programme was to select strains of Lotus for stronger late winter and early spring growth, and Maku lotus has subsequently been reported to show improved cool season activity (Corkill *et al.,* 1981). It was not specifically developed for the extreme conditions of South Island high country, and the improved cool season activity was achieved by incorporating selected Mediteranean parentage which could have increased its vulnerability to harsh climatic conditions.

Trials have been conducted under conditions where it is possible to examine both soil fertility and climatic limitations on production. The low yields of lotus on soils of low P and S status, in the absence of either P or S fertiliser confirm the earlier results for the Lammerlaw-Lammermoor series (McIntosh et *al.,* 1984). The results show that soil tests are effective in identifying the need for P and S fertilisers. Where soils contained less than about 10 ug/g P in Olsen tests there were very highly significant responses to applied P, but at P levels above about 15 responses were much reduced. Questions, however, do arise as to how much P is required, and whether the requirements of lotus and clovers are significantly different. Responses to incremental rates of fertiliser, where at least 60% of maximum production was obtained from the smallest rate of application, lead to the conclusion that an initial application of 20 kg P (250 kg/ha superphosphate) followed by 10 kg P (125 kg/ha superphosphate) annually should largely overcome P deficiency in lotus in most situations in the South Island high country.

Almost all of the soils at the sites studied were low in S (phosphate extractable soil SO& less than about 10 ug/g) although deficiency was generally more severe, and soil test values were lower, on the Lammerlaw-Lammermoor sequence than on the Remarkables (Table 1). From responses to incremental rates of S on the S-deficient sites on the Remarkables it is concluded that the recommended rates of superphosphate (250 kg initially followed by 125 kg/ha annually) would supply adequate S (28 kg/ha initially and 14 kg/ha annually) to overcome S deficiency in lotus in most situations. To ensure the elimination of S deficiency, sulphur-superphosphate (0-8-O-19) could be used. This would increase fertiliser costs by about 25% compared with applying the same amount of P in superphosphate. Because of the S requirements of lotus for satisfactory pasture growth in the sites we have studied, sulphur-free fertilisers (DAP, triple superphosphate, rock phosphate) cannot be recommended unless soil S tests are high, or supplementary S is added.

There was little evidence that the amounts of fertilisers required by clovers were significantly different from the requirements of lotus to reach the same yield. There were, however, occasional indications that clover might continue to respond to higher fertiliser rates than lotus. Lime was required for maximum production from clovers at all sites on the Lammerlaw-Lammermoor sequence, but it was of no benefit to lotus providing soil pH was above 4.5. These results are generally in accord with those of Lowther (1980) who showed that broadcast lime had beneficial effects (over and above the effects of pelleting) on the establishment and growth of clover, but only on the establishment of lotus on an upland yellow-brown earth with a pH of 4.6 - 4.8.

The very much lower lotus yields on the Lammerlaw-Lammermoor sequence of sites compared with higher production (up to 7000 kg DM/ha) on the Remarkables requires some explanation. Nutrient supply, moisture supply and temperature are the most likely limiting factors and the first can be eliminated because near maximum yields were obtained at all sites with less than maximum fertiliser rates and no other nutrient deficiencies were evident from herbage chemical analyses. On the Lammerlaw-Lammermoor sequence of trials moisture deficiency is unlikely to be a serious limitation to production except where rainfall is less than about 1000 mm, (Table 1), which could occur at sites below 1000 m. During the drier 1980-82 period the production of lotus exceeded that of clover (McIntosh et *al.,* 1984) and clover may have been limited by moisture supply. In 1983-84, when rainfall was above average, yields of clover on these lower altitude sites exceeded lotus, resulting in similar mean annual yields for the two species over the 4 years. Moisture supply does not, however, account for the gross differences between the Lammerlaw-Lammermoor and Remarkables series of trials because the latter have been very much more productive in every year.

Low temperature, short growing season, or frequency and severity of frost are likely to be important factors limiting production especially at the highest elevations but reliable data are not available to compare the conditions on the Remarkables and on the Lammerlaw-Lammermoor sequences. Calculated mean annual soil temperatures at 30 cm, based only on altitude and latitude (Table 1) indicate slightly higher values at corresponding altitudes on the Remarkables but these are not sufficiently different to account for a 2 to 3 fold difference in yield. The greater temperature lapse rate on the Rock and Pillar Range, (near the Lammerlaws) compared with the Remarkables (Meurk, 1982) may help to explain the more rapid fall off in lotus yield above 1000 m on the Lammerlaws. Field evidence and observation suggests that frost damage is more prevalent and severe on the Lammerlaws, and that growth is later to start here than on the Remarkables. Lotus growth also starts later than that of clover at all sites. McIntosh *et al.,* (1984) suggested that low temperature is likely to be the explanation for low production at high altitude on the Lammerlaw Range. Mitchell (1956) showed that lotus had a higher optimum temperature for growth than white clover, which could help to explain the better growth of clover relative to lotus at high altitudes on the Lammerlaw Range. Climatic data, collected locally, on accumulated day-degrees, length of growing season and frost frequency will be required for a proper interpretation of the observed data. If reliable advice is to be given concerning areas best suited to lotus production, then more information on the geographic distribution of climatic constraints will also be needed, similar to the bioclimatic classification of England and Wales (Bendelow and Hartnup, 1980). Because of the unsuitability of Maku lotus in areas of most severe climate, there is also a case to continue the search for legumes better adapted to harsh climatic conditions.

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REFERENCES

Barclay, P.C. 1957. *Proc. N.Z. Grassld Ass. 19:* 75-81.
________ 1960. *Proc. 8th Int. Grassld Cong.* 326-330.
________; Lambert, J.P. 1970. *Proc. 11th Int. Grassld Cong.* 278-281.
Bendelow, V.C.; Hartnup, R. 1980. *Soil Survey Technical Monograph No. 15.* Rothamsted Experimental Station, Harpenden, U.K.
Brock, J.L. 1973. N.Z. *J.* agric. Res. 76: 483-91.
Corkill, L.; Williams, W.M.; Lancashire, J.A. 1981. *Proc. N.Z. Grass/d Ass. 42:* 100-122.
During, C.; de Rosa, R.; Martin, D.J. 1964. *Ibid 26: 62-67.*
Greenwood, R.M. 1961. *N.Z. J. agric. Res. 4: 375389.*
Levy, E.B. 1951. Grasslands of New Zealand. Government Printer, Wellington.
Lowther, W.L. 1977. *Proc. N.Z. Grassld Ass. 37: 221-227.*
________ 1980. *N.Z. J. exp. Agric. 8:* 131-138.
McIntosh, P.D.; Backholm, G. 1981. *Tech. Report* No. *10.* Invermay A.R.C., MAF.
________; Lee, W.G.; Banks, T. 1983. N.Z. *J. Sci. 26:* 379-401.
________; Enright, P.D.; Sinclair, A.G. *1984. N.Z. J. exp. Agric. 72:* 119-129.
Meurk, CD. 1982. Alpine phytoecology of the rain shadow mountains of Otago and Southland, New Zealand. PhD. Thesis, University of Otago.
Mitchell, K.J. 1956. N.Z. *J. Sci. Tech. 37A:* 395-413.
Morton, J.D. 1981. *Proc. N.Z. Grassld Ass. 42:* 123-130.
Nordmeyer, A.H.; Davis, M.R. 1977. *Ibid. 38:* 119-125.
Scott, D.; Stringer, G.C.; O'Connor, K.F.; Clifford, P.T.P. 1974. *N.Z. J. exp. Agric. 2: 251-259.*
Thomas, R.F.; Blakemore, L.C.; Kinloch, D.I. 1980. *N.Z. Soil Bureau Scientific Report* 398. D.S.I.R.