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EFFECTS OF LIME AND ALTITUDE ON THE PERFORMANCE OF PASTURES -BASED ON SIX ALTERNATIVE LEGUMES FOR ACID TUSSOCK GRASSLANDS

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Abstract

Two lotus and 4 clover cultivars were oversown at 3 tussock sites ranging in altitude from 460 to 1040 m. The sites were initially similar in soil chemical characteristics, aspect and topography, so that differences were attributable mainly to increasing severity of climate. The objectives were to determine the extent to which legume choice is affected by(a) lime to raise soil pH, and(b) increasing seventy of climate.

In the first year 'Grasslands Pawera' red clover wards were Outstanding at the lower sites. With time the superiority of Pawera was overtaken by 'Grasslands Maku' and Maitland lotus. Maku wards were outstanding in the absence of lime (UP to 5.5 t DM/ha at 460 m, and up to 2 t DM/ha at 760 m) in years 2-3-4, and Maitland lotus wards produced up to 5 t DM/ha with lime at the lowest site, but did not perform well without lime At the highest site, lotus-based pasture did not perform consistently as well as the white clover wards. At all sites lime greatly increased both the legume content of the swards and total pasture production for at least 4 years. Generally Maitland lotus gave the greatest and Maku lotus the least responses to lime.

Keywords: lotus, clover, Maku, Maitland, Huia, Tahora, Pawera, Tetra, lime, altitude, tussock grasslands, legumes

INTRODUCTION

'Grasslands Huia' white clover (*Trifolium repens*) has conventionally been used for tussock grassland pasture development. 'Grasslands Maku' lotus *(Lotus pedunculatus*) has been promoted as an alternative for acid and lower fertility soils (Scott & Mills 1981), and these legumes were compared in studies by Lowther (1980), McIntosh et al. (1984) and Floate et al. (1985). The last two studies defined the fertiliser requirements for the establishment of pastures based on these legumes at altitudes ranging between 600 and 1200 m on tussock grasslands in Otago and showed that the two legumes responded differently to increasing altitude at contrasting sites on the Lammerlaws and on the Remarkables. They also demonstrated significant responses to 4 t/ha lime but Lowther (1980) obtained significant responses to only 1250 kg/ha lime.

The effectiveness of lower and hence more economic rates of lime, and the choice of the most productive legume with respect to altitude, are outstanding questions arising from the previous work To resolve these questions a series of 3 trials were established in 1983. In these trials 6 commercially available legume cultivars were compared at altitudes of 460,750 and 1040 m, with 5 lime rates up to 4 t/ha, and 3 rates of superphosphate.

Results from this series of 3 trials, show that 1 t/ha was the optimum lime rate, and confirm that an initial application of 250 kg/ha molybdenised superphosphate is adequate for legume establishment (Floate et *a/.* 1988). Production can be maintained with 125 kg/ha superphosphate annually under a clippings removal technique. The results for the 6 legumes, for the first 4 production years, at 3 sites, but restricted to this standard fertility level, with and without lime at 1 t/ha, are described in this paper..

SITES, MATERIALS AND METHODS

The sites were chosen so that initially their soil chemical properties were as nearly similar as was practicable (Table 1). All were acid (pH 4.5-4.7) and low in phosphorus (P) and sulphur (S). The trials were situated in undeveloped tussock grassland on gentle slopes with easterly aspect at 460,750 and 1040 m altitude, so !hat differences were attributable mainly to increasing severity of climate with increasing altitude.

Table 1: Site and soil characteristics of field trials

Property	Site 1	Site 2	Site 3
Location	Waipori	Castle oent	Ailsa Craig
Map reference (NZMS 1)	5162'582676	S162 435838	S153 582003
Soil pH	4.66	4.55	4.52
Olsen-P (µg/ml)	6 9	2.8	5.9
Sulphate (µg/g)	12.5	6.7	6.2
Growing season days with mean temp > 5 °C	245	231	175
Altitude (m)	460	750	1040

Six commercially available legume cultivars, 'Grasslands Huia' and 'Grasslands Tahora' white clovers, (Trifolium repens), 'Grasslands Pawera' red clover (Trifolium pratense), Tetra alsike clover, (Trifolium hybridum), 'Grasslands Maku' lotus (Lotus pedunculatus) and Maitland birdsfoot trefoil (Lotus corniculatus), were oversown in small plots (2 x 4 m) in virgin tussock grassland in spring 1983. The sites were previously trimmed to simulate tussock burning and regrowth, and seeding rates were adjusted to supply the same number of seeds per unit area, equivalent to 6 kg/ha Maku lotus. All clovers and Maitland trefoil were inoculated and lime pelleted while Maku lotus was only inoculated (Lowther 1976). Only at the lowest site was any herbage cut in the first year and data are presented here for the first 4 full production years: 1984-85, 198586, 1986-87 and 1987-88 (years 1, 2, 3 and 4). Although there were a total of 11 fertiliser x lime treatments in the trials, data are presented here only for the standard level of fertility, with and without lime. Initially (1983) 1 t/ha lime plus 250 kg/ha molybdenised superphosphate was applied, and annual maintenance was at the rate of 125 kg/ha superphosphate.

Production was measured using a sickle-bar mowing procedure, with 5 cm cutting height, and with no clippings returned. Results are presented for total annual herbage dry matter (DM), and for percentage legume content of the herbage.

RESULTS AND DISCUSSION

At the lowest site (Waipori at 466 m, Table 2), Pawera swards were outstanding both with and without lime, in year 1. The large bulk of above-ground production could make a large contribution (particularly nitrogen) to soil fertility, but Pawera lacked persistence at this site.

The early superiority of Pawera swards was overtaken by lotus swards in year 2. Without lime, Maku lotus swards were individually superior in year 2, and were consistently among the highest yielding swards in years 3 and 4. When lime was applied at establishment, Maitland lotus swards were among the most productive in years 2-3-4.

Lime had a very marked effect on the legume content of all swards, especially in years 1 and 2. Lime also increased pasture production by up to 3.7 t DM/ha, and on

Table 2: Total annual pasture production for 6 legume cultivars, for 4 years at the standard fertility level. with and without lime: kg DM/ha and percent legume content of sward (in brackets) for Waipori at 460 m.

	White clovers		Other clovers		Lotus species	
	Huia	Tahora	Tetra	Pawera	Maitland	Maku
Treatment 1: Initially 250 kg/ha Mo superphosphate						
1984-85 **(Year 1)**	3265(31)	2950(22)	2714(44)	4735(72)	1221(57)	3398(42)
85-86 (Year 2)	2442(5)	2203(3)	1445(21)	2728(55)	2416(62)	3926(48)
86-87 (Year 3)	2750(19)	2441(11)	1924(36)	2590(32)	3071(59)	3593(53)
87-88 (Year 4)	4026(16)	4377(7)	3123(13)	3993(23)	4235(19)	5467(44)
Treatment 2: Initially 250 kg/ha Mo = superphoshpate plus 1 t/ha lime						
1984-85 **(Year 1)**	4070(68)	2840(66)	4429(78)	6175(89)	4965(76)	4397(78)
85-86 (Year 2)	2919(25)	2061(20)	2861(40)	3601(72)	4392(75)	4331(71)
86-87 (Year 3)	2383(23)	1913(20)	2817(35)	2380(64)	4316(74)	3812(62)
87-88 (Year 4)	4203(17)	3447(8)	4169(37)	4229(40)	5230(46)	5858(46)
SED (For all comparisons in any 1 year)						
1984-85 **576**						
85-86 **521**						
86-87 **378**						
87-88 **584**						

Table 3' Total annual pasture production for 6 legume cultivars, for 4 years at the standard fertility level, with and without lime: kg DM/ha and percent legume content of sward (in brackets) for Castle Dent at 750 m

	White clovers		Other clovers		Lotus species	
	Huia	Tahora	Tetra	Pawera	Maitland	Maku
Treatment 1; Initially 250 kg/ha Mo superphosphate						
1984-E (Year 1)	715(11)	629(6)	780(19)	962(20)	724(16)	1144(8)
85-86 (Year 2)	845(3)	744(5)	1082(7)	1116(23)	917(42)	1949(28)
86-87 **(Year 3)**	634(24)	654(22)	576(31)	51 1(23)	929(43)	I&399(66)
87-88 **(Year 4)**	1267(16)	1458(14)	969(12)	1169(5)	1320(27)	2149(41)
Treatment 2' Initially 250 kg/ha Mo = superphosphate plus 1 t/ha lime						
1984-85 **(Year 1)**	176 1(60)	1599(54)	1985(66)	3066(75)	2101(67)	2032(64)
85-86 (Year 2)	1773(42)	1714(41)	1592(44)	2662(61)	2766(75)	3164(71)
86-87 **(Year 3)**	1743(21)	1774(18)	1276(40)	1255(38)	1691(70)	2773(66)
87-88 **(Year 4)**	2547(19)	2674(26)	1419(11)	1 800(10)	1837(26)	2699(48)
SED **(for all comparisons in any 1 year)**						
1984-85 **334**						
85-86 **266**						
86-87 **318**						
87-88 **265**						

average the limed Maitland swards produced an extra 2 t DM/ha.

At the mid-altitude site (Castle Dent at 750 m, Table 3) Pawera swards were outstanding in the first year with lime, but this superiority was short lived. Without lime, Maku lotus swards were among the highest yielding in year 1, and were clearly outstanding in years 2-3-4. Maitland lotus swards were consistently among the highest producing with lime, but did not perform well without lime.

Lime increased pasture production by up to 2.1 t DM/ha (Pawera) and gave an extra 1 t DM/ha on average over 4 years with both Pawera and Maitland lotus. Maku lotus and Tetra alsike clover swards gave the least responses to lime. Lime also markedly increased the legume content of all swards.

At the highest site (Ailsa Craig at 1040 m, Table 4) the production of all legumes was low, and less than 0.5 t DM/ha in the first year. Most of this bulk was composed of non-legume (native and resident grass) especially in the unlimed treatment, and

in year 2 the sown legumes made a much increased contribution to production. Without lime only the Huia white clover sward in year 3 exceeded 2 t DM/ha, but with lime Huia, Tahora and Tetra clovers and Maku lotus yielded more than 2 t DM/ha in year 2 and all cultivars exceeded this production in Year 3. When lime was applied Huia, Tahora and Tetra clovers always ranked among the top 4 cultivars. There was little difference between cultivars in the production of legume DM although there did appear to be an improvement with time in the yield of both lotus cultivars as these increased as components of the sward. However, the white clover-based swards gave the highest total pasture production, especially where lime was applied, because of their greater grass component. The low production of Pawera swards in the first 2 years, and high production in the year 3, may be due to selective grazing by hares in the early years, followed by recovery after control of hares.

Lime increased pasture production by up to 1.6 t DM/ha (Maitland) and on average Tetra and Pawera clover swards gave an extra 1 t DM/ha with lime. Maku lotus gave the least response to lime.

Table 4 Total annual pasture production for 6 legume cultivars. for 4 years at the standard fertility level, with and without lime: kg DM/ha and percent legume content of sward (in brackets) for Ailsa Craig at 1040 m.

	White clovers		Other clovers		Lotus species	
	Huia	Tahora	Tetra	Pawera	Maitland	Maku
Treatment 1: Initially 250 kg/ha Mo- superphosphate						
1984-85 (Year 1)	482(3)	474(1)	333(6)	364(2)	205(1)	31 0(2)
85-86 (Year 2)	1542(26)	1316(25)	805(33)	466(24)	503(46)	1122(51)
86-87 (Year 3)	2454(46)	1747(36)	1036(51)	1462(72)	787(66)	1417(82)
87-88 (Year 4)	1464(22)	699(7)	293(29)	509(25)	385(61)	987(24)
Treatment 2: Initially 250 kg/ha Mo = superphosphate plus 1 t/ha lime						
1984-85 (Year 1)	593(25)	415(29)	674(43)	262(1)	320(9)	510(24)
85-66 (year 2)	2138(52)	2128(62)	2152(72)	830(37)	1377(71)	2055(76)
86-67 (Year 3)	3120(41)	3250(57)	2771(76)	4130(92)	2399(85)	2346(80)
87-88 (Year 4)	1828(29)	1221(15)	1364(45)	1580(57)	1292(74)	1063(17)
SED (for all comparisons in any 1 year)						
1984-85 227						
85-86 408						
86-87 483						
87-88 414						

GENERAL DISCUSSION

At all sites (Tables 2, 3, 4) the effects of lime were not only to increase significantly total herbage production, but also the legume content of almost all swards. The sward effect was most marked at Castle Dent in years 1 and 2, and at the highest site in year 2. The greater responses at the higher altitude sites may be related to their lower starting soil pH than at Waipori. Diminishing lime response with time, demonstrated by Maku and Maitland swards at the lower sites is similar to the observations on Maku lotus by McIntosh et *al.* (1984).

Traditionally pasture plants with a wide genetic base, such as Nui ryegrass and Huia white clover, have been used over the whole range of soil and environmental conditions in New Zealand. Increasingly cultivars are becoming available for more specialised uses in more Particular situations (Charlton & Thorn 1984; Scott et al. 1985; Keoghan 1985). The last two papers discussed the choice of species for South Island hill and high country conditions, and the work presented here provides further evidence for basis of choice.

Ultimately selection should be based on performance under real farm conditions including grazing selection pressure. The conditions of this trial are artificial in that they do not include nitrogen cycling from legume to grass via grazing or litter, with the consequence that under grazing total production of all the swards and especially those with high legume content may have been higher, and the lotus cultivars may be at a disadvantage in the present comparisons. The legume content of the lotus-based swards remained high into ***year*** 3, but the legume content, particularly of the white clover-based swards, had diminished and the resident grass component had increased, suggesting more effective underground nitrogen transfer to associated grasses.

Thus, although an initially important aspect of pasture improvement in these tussock grasslands is the enhanced quality associated with high legume content, as fertility builds up and nitrogen is transferred to the grasses, the legume content of thes sward falls back from a peak. In year 4, there were indications that this was beginning to occur also in the lotus swards at the lower altitudes. Although Maku lotus has compared favourably in these trials, especially at the lower altitudes, and without lime, it may have performed even better under grazing, because Lowther (pers. comm.) has shown this cultivar to be accompanied by better grass growth under grazing conditions. Maitland lotus has demonstrated considerable potential, and has responded to relatively low lime treatments.

Performance of both lotus swards was restricted at the highest site. This result appears to conflict with data for the Remarkables (Floate et ***al.*** 1985) where Maku lotus swards out-yielded clover-based swards at all altitudes, but out-yielded clover swards only at the lower altitudes on the Lammerlaws. The present results are comparable with those previously reported for the Lammerlaws, and the differences may be due to higher mean temperatures and the longer growing season on the Remarkables (Enright & Floate 1988).

CONCLUSIONS

The work presented here permits a comparison of 6 legume cultivars at 3 altitudes, 460, 750 and 1040 m, on very acid soils both with and without lime, and with similar nutrient inputs at all sites. Given the limitations of cutting trials, the data suggest that Maku lotus is best adapted to moderate fertility and has greater acid-tolerance than Maitland lotus and the 4 clover cultivars tested. Lowther et a/. (1987) concluded that lack of tolerance to soil acidity was likely to limit use of Lotus *corniculatus* on more acid soils. The present work has shown that even on very acid soils, application of 1 t lime/ha allows a sward of Maitland lotus to develop within 2 years, and to at least equal and frequently exceed production of clover-based swards under the same conditions at the low- and mid-altitude sites. Sward composition data show that lime is particularly important for the rapid establishment of a satisfactory legume component in pasture, especially at mid to higher altitudes.

The initial outstanding performance of Pawera red clover indicates its potential as a pioneer plant, able to produce a large bulk of nitrogen-rich organic matter and to build up soil fertility where the transfer mechanisms are in place. For this reason this cultivar probably has an important role in sward development, and the build-up of conditions to enable associated grasses to flourish.

Lotus swards took a little longer than clover swards to develop, but after the first year Maku swards were consistently among the highest yielding swards without lime at the lower altitude sites. Maitland lotus swards performed well at the lowest site with lime and consistently gave the greatest responses to lime.

Lime was beneficial in producing significant yield increases in excess of 1 t DM/

ha at all sites (and up to 3.7 t DM/ha at the lowest site) and also marked increases in legume content (and hence pasture quality). These effects persisted for at least 4 years and we are continuing to measure the duration of these responses.

This research has provided sound evidence upon which to base lime recommendations for oversown legumes in acid tussock grassland soils.

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