THE RESPONSE OF SIX LEGUME CULTIVARS TO INCREASING SEVERITY OF CLIMATE IN SOUTH ISLAND HIGH COUNTRY

P.D. Enright, M.J.S. Floate
Plant Soil and Engineering Sector, MAFTech
Invermay, Private Bag, Mosgiel

ABSTRACT

Six legume species: *Trifolium repens*, c.v. Grasslands Huia and Tahora white clovers; *Trifolium pratense*, c.v. Grasslands Pawera red clover; *Trifolium hybridum*, c.v. Tetra alsike clover; *Lotus pedunculatus*, c.v. Grasslands Maku lotus; and *Lotus corniculatus*, c.v. Maitland birdsfoot trefoil were oversown in Spring 1983 at three tussock grassland sites of similar aspect and soil fertility but spanning the altitude range 450-1050 m. Dry matter (DM) production was measured in 1984/85 and 1985/86 and related to soil and air temperatures and degree of environmental exposure.

Mean daily air and soil temperatures declined by up to 3 °C from 450 to 1050 m while frosting and exposure increased with altitude.

In 1984/85 DM yields from all cultivars decreased with increasing altitude and decreasing soil and air temperatures but in 1985/86 although both lotus species and Pawera red clover followed the previous year's pattern the yields from Tahora, Huia and Tetra alsike showed no clear pattern of decline with altitude. This was attributed to strong competition from the resident grasses, browntop and sweet vernal, especially at lower altitudes.

As swards matured the effect of increasing climatic severity was generally greater on the two lotus species than on clovers.

Additional Key Words: Legumes, climate, tussock grasslands, temperature, exposure.

INTRODUCTION

Many alternative legumes to the conventional Huia white clover are being considered for pasture development on acid and low fertility soils such as the upland and high country Yellow Brown Earths. Lowther (1980), McIntosh *et al.* (1984), Floate *et al.* (1985 and 1988) and Keoghan *et al.* (1988) have shown that many legumes including Maku and Maitland lotus have considerable potential, provided establishment and fertiliser and lime requirements are met. They have also shown that the effect of increasing altitude on production may differ between species and that this effect is not necessarily attributable to altitude per se.

This paper considers how soil and air temperatures and exposure changed with increasing altitude between 450 and 1050 m, and relates these to production changes from six commercially available legumes oversown on the East Otago plateau.

EXPERIMENTAL

In Spring 1983, *Trifolium repens*, c.v. Grasslands Huia and Tahora white clovers; *Trifolium pratense*, c.v. Grasslands Pawera red clover, *Trifolium hybridum*, c.v. Tetra alsike clover, *Lotus pedunculatus*, c.v. Grasslands Maku lotus and *Lotus corniculatus*, c.v. Maitland birdsfoot trefoil were oversown at 530 seeds/m² in 2 × 4 m plots replicated in three blocks. Three sites, at 450, 750 and 1050 m on the East Otago Plateau were selected so that gentle slope, north easterly aspect and natural fertility level were as nearly similar as possible. Production difference could thus be attributed mainly to changing severity of climate with altitude. All clovers and Maitland lotus were inoculated and lime pelleted while Maku lotus was inoculated only (Lowther, 1976). Plots were harvested two or three times annually using a sickle bar mower and dry matter yields and legume proportions determined.

The sites chosen were originally acidic and low in fertility, so an initial lime and fertiliser application (Floate *et al.*, 1988) of 1 t/ha lime and 250 kg/ha molybdenum-superphosphate, and standard annual maintenance of 125 kg/ha superphosphate was applied to all treatments. Table 1 details the prior nutrient status and also that of Spring 1985 by which time 1 t/ha lime and a total of 375 kg/ha superphosphate had been applied.

Soil temperatures at 10 cm depth and air temperatures measured at Stevenson Screen height, i.e. 1.5 m, have been

TABLE 1: Soil nutrient status in (a) 1983, (pre-treatment) and (b) 1985, after two seasons and when a total of 375 kg/ha Superphosphate and 1 t/ha lime had been applied.

Site		1	2	3
Altitude (m)		450	750	1050
(a) 1983	pH	4.7	4.6	4.6
	Olsen-P	7	3	6
	SO_4-S	13	7	6
(b) 1985	pH	4.9	4.7	4.7
	Olsen-P	7	7	15
	SO_4-S	27	21	18

drawn from data collected between October 1984 and May 1986 (Enright and Heenan, 1987). The authors recognise some problems in the interpretation of the data because of gaps in collection due to equipment failure. However, these problems have been minimised by fitting a cosine model to produce smoothed annual temperature curves for each site. This statistical procedure used all the data available over the two seasons to produce these curves. The smoothed annual curves were also used to determine the number of days that the mean daily temperatures were greater than 5 °C. It should be noted that the means used in this data set are averaged over each 24 hour period, and that mean soil temperatures may differ from standard soil temperature data recorded at 9.00 am each day.

Exposure, which is the combined effect of wind direction and strength as well as rainfall, was measured at each of the sites between 13 November 1985 and 1 April 1986 using "Tatter" flags, a method used by the British Forestry Commission for nearly thirty years (Lines and Howell, 1963) and more recently in New Zealand. Flags consist of a square of cloth of standard grade and dimensions attached to a stainless steel pole by swivel rings. When placed in an exposed site the action of wind and rain causes the flag to fray away at a rate (cm^2/day) that is correlated to the degree of exposure.

RESULTS

Climatic Temperatures

Temperature data are summarised in Table 2. Extreme air maxima at the three altitudes ranged between 28.0 and 24.5 °C while minima ranged between −3.3 and −8.5 °C.

Annual mean daily air temperatures were 8.3, 7.4 and 5.5 °C at 450, 750 and 1050 m respectively. Mean maximum and mean minimum temperatures followed a similar pattern.

The number of days that mean daily temperatures were in excess of 5 °C decreased with increasing altitude from 274 at 450 m to 191 at 1050 m.

The periods during which the air temperature was below 0 °C increased with increasing altitude. These periods of air frosting also began earlier in the autumn and continued longer into the spring with increasing altitude. However, gaps in data collection prevented a more detailed examination of this data. Fraser *et al.* (1988) have also recorded an increase in severity and frequency of frosting over the same altitude range.

Extreme soil maxima at these three sites ranged between 22.5 °C and 18.5 °C while minima ranged between −0.2 and −5.5 °C.

Annual mean daily soil temperatures at 450, 750 and 1050 m were 7.2, 7.5 and 4.9 °C respectively. A similar relationship between temperature and altitude was noted in mean maximum, and mean minimum daily temperatures. The warmer temperature at 750 m compared with 450 m may have arisen from less severe ground frosts or more snow cover (insulating effect) at this site during this period.

As with air temperatures the number of days that mean daily soil temperatures were greater than 5 °C decreased with increasing altitude.

Exposure

Exposure was measured between 13 November 1985 and 1 April 1986 and for a similar period in the following season using three tatter flags at each site. The average daily rates of tatter (material loss or Tatter Index) at 450, 750 and 1050 m were 3.9, 4.3 and 6.2 cm^2/day respectively. In the UK, the following ranges of Tatter Index have been adopted to indicate degrees of exposure:- sheltered 0-3.9 cm^2/day; moderately exposed, 4.0-6.5; very exposed 6.6-10.0; and extremely exposed 10.1+. Using these exposure classes, the rates of tatter at our sites indicate a range of exposure between sheltered to moderately exposed at the lowest altitude and approaching very exposed at the highest altitude. Similar observations were made in the following season. It is notable that daily wind run data from nearby sites at similar altitudes show close concordance with the Tatter index (Table 2).

TABLE 2: Climatic data at three altitudes on the East Otago Plateau.

Altitude	450 m		750 m		1050m	
	Air	Soil	Air	Soil	Air	Soil
Extreme maximum (°C)	26.0	22.5	28.0	18.5	24.5	19.7
Mean maximum (°C)	12.7	14.1	12.1	13.4	10.6	10.6
Daily mean (°C)	8.3	7.2	7.4	7.5	5.5	4.9
Extreme minimum (°C)	-3.3	-0.8	-5.5	-0.2	-8.5	-5.5
Mean minimum (°C)	3.8	0.4	2.7	1.6	0.4	-0.8
Mean temp > 5 °C (days)	274	157	241	169	191	120
Tatter index (cm^2/day)	3.9		4.3		6.2	
Daily wind run (km/day)[1]	335		417		622	
Rainfall (mm)[2]	651		1076		1007	

[1] Mean of 12 years data at 450 m, and 5 years data at 750 m respectively (G. Cossens, pers. comm.) and mean of 2 years data at 1050 m (Dawber *et al* 1979). Anemometer sites were either identical to trial sites (750 m) or within 10 km (450 and 1050 m).

[2] Mean of 6 years data at 450 m and 750 m (G. Cossens) and from short term Ministry of works records at 1050 m (McIntosh and Backholm, 1981).

Legume Production

Legume dry matter data are presented for the 1984/85 (year 1) and 1985/86 (year 2) seasons (figure 1). In year 1 yields from all species were significantly less at higher altitudes. At the lowest site, yields from the six legumes ranged between 1,880 kg/ha (Tahora) and 5,490 kg/ha (Pawera). Yields at the intermediate site were approximately 40% of those at the lowest site while at the highest site yields of all cultivars were less than 10% of those at the lowest site. At the two lower sites, Pawera was the outstanding cultivar while Maku, Maitland and Tetra were intermediate and white clovers poorest.

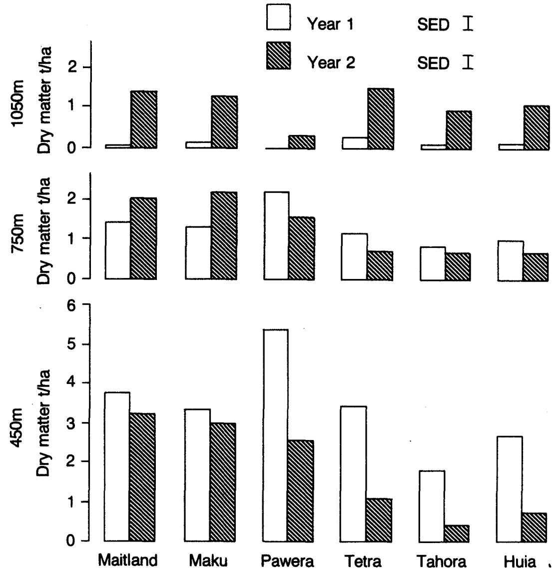

Figure 1: Annual Legume yields at 3 altitudes for year 1 (1984/85) and year 2 (1985/86).

In year 2, yields from Maitland, Maku and Pawera continued to demonstrate the same pattern of decrease with increasing altitude seen in year 1, but Tetra, Tahora and Huia showed no clear relationship with altitude.

Yields in year 2 at the highest site increased markedly compared to year 1, (up to 1700 kg/ha DM for Maku) while at the lowest site they decreased. Also Pawera in year 2 was ranked below Maitland and Maku.

Several points should be noted. Increasing legume yields at 1050 m in year 2 were also accompanied by large increases in the legume content of swards from all species (Figure 2). At 450 and 750 m there was little change in legume content of Maitland, Maku and Pawera swards (less than 10%) while with Tetra, Tahora and Huia swards there was a large decrease in legume content due to an increase in associated companion grass.

Yields in year 3 (not presented) showed similar responses to those recorded in year 2.

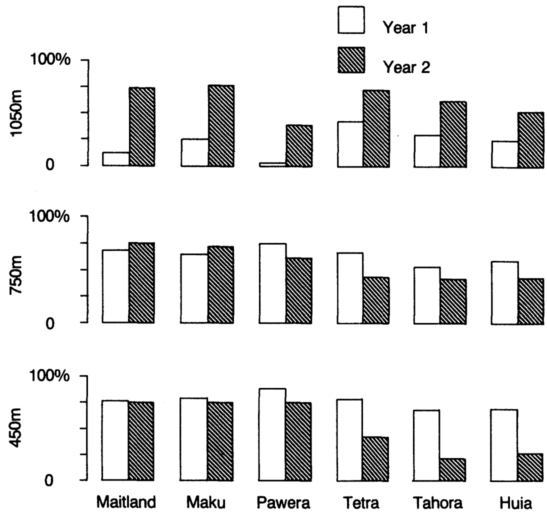

Figure 2: The proportion of legume in the total swards at 3 altitudes for year 1 (1984/85) and year 2 (1985/86).

DISCUSSION

The results show that the three sites formed a temperature gradient in which mean annual soil temperatures decreased by up to 2 °C with increasing altitude, while mean annual air temperatures decreased by about 2.9 °C over the 600 m range from 450 to 1050 m. This compares favourably with data collected from the same sites between December 1987 and April 1988 (Fraser *et al.*, 1988) where, over the same altitude range mean daily soil and air temperatures decreased from 11.0 to 9.7 and 9.7 to 7.7 respectively.

The lapse rate (air temperature decrease with increasing altitude) increased with increasing altitude from 0.30 °C/100 m over the 450-750 m range to 0.63 °C/100 m over the 750-1050 m range. This was similar to that reported by Mark (1965) on the Old Man Range where it increased from 0.51 to 0.72 °C/100 m and by Cossens (1982) on the Rock and Pillar range where it increased from 0.46 to 0.63 °C/100 m, both for altitude ranges similar to our study. Barringer (1987) has also shown that the lapse rate on the north face of The Remarkables was less below 950 m (0.45 °C/100 m) than above 950 m (0.55 °C/100 m).

The use of tatter flags to measure exposure in New Zealand has been reviewed by NZ Forest Service (Tombleson, pers. comm.) who concluded that valid comparative data could be achieved provided flags were used within restricted geographic limits. He also noted that good relationships between anemometer records and flags exposed concurrently have been recorded. Our sites were chosen with similar aspect and topography and located within a distance of 50 kilometres, so rate of tatter at these three sites should give valid comparisons. The data showed a close concordance between wind run and tatter-rate and based on the four tatter-rate exposure classes used in the UK, our data show that exposure ranged between sheltered at 450 m, to approaching the very exposed class at 1050 m.

The effect of these temperature and exposure gradients on legume production was highly significant and more severe in the first year than the second.

Maitland and Maku lotus, and Pawera red clover yields were clearly related to increasing altitude and climatic severity in both years while Tetra alsike, Tahora and Huia clover decreased with altitude in year 1 only. In year 2, yields from Tahora were greater at higher altitudes while Tetra and Huia showed no clear pattern with increasing altitude. The lack of a consistent decline in yields from these cultivars with increasing altitude is probably due to increased competition from vigorous grass growth at lower altitudes causing smaller than expected legume yields. This combined with large increases in legume content and yield in year 2 compared with year 1 at the highest altitude have confounded the expected relationship with altitude. Data for total sward production (grass plus legume yield not presented here) show a clearer relationship between increasing altitude and decreasing yield. It is notable that Tetra, Tahora and Huia swards at 450 m and 750 m have progressed from legume dominant swards in year 1 to grass dominant swards in year 2, but this has not yet happened at higher altitudes. Therefore it would appear that Tetra, Tahora and Huia swards have matured more quickly at lower altitudes compared to higher altitudes.

The proportion of grass in Tetra, Tahora and Huia swards was greater than that of other legumes and this may have arisen from the management employed. Lowther (pers. comm.) suggests that under grazing, there would be more recycling and probably higher grass content in Maku, Maitland and Pawera swards and therefore the consistent and relatively large decline with altitude in yields from these species may not have been so evident. These results highlight the complex nature of this type of work where so many factors may influence production.

Very low Pawera red clover yields were recorded in both seasons at the highest site and this resulted from selective grazing by hares. In subsequent years with more rigorous hare control, yields were much greater.

CONCLUSIONS

The results of this work show that on the East Otago Plateau a relatively small increase in altitude (600 m) has caused a decrease in legume yields of up to ten fold. It is considered that this effect on production could not have been the result of the small change in temperature alone, but was likely to be due to the combination of both decreasing temperature and increasing exposure.

A comparison of yields indicated that Pawera was the best legume at lower altitudes and early stages of pasture development. Maitland and Maku out performed both white clovers at the lower altitudes while at the highest altitude there was little difference between lotus and clover yields. Tahora white clover was slow to develop compared to other legumes.

The effect of increasing altitude and climatic severity was greater on yields from Maitland, Maku and Pawera than Tetra, Tahora and Huia and at the highest altitude sward development was delayed by up to 2 years compared to the lowest site.

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