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PERSISTENCE AND GROWTH OF MAKU LOTUS ON CONTRASTING ASPECTS AT HIGH ALTITUDE

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Abstract

Maku lotus plants were grown in snow tussock grasslands at 1460 m altitude on steep ungrazed slopes. A total of 960 plants were transplanted in spring 1980 to five sites. In March 1984 survival was 72% and 68% on two NW sites and 66%, 56% and 46% on three ESE sites. Survival rates did not differ between 100 and 300 kg/ha sulphur enriched superphosphate applied in the transplant year, but dense native vegetation appeared to contribute to poorer survival on the eastern slopes.

Mean lotus plant size, expressed as an index of ground spread was consistently larger on NW than on ESE, and in February 1984 was three times larger (1422 cm^2 cf. 429 cm^2). Mean DM yields per plant in February and March 1984 were from 1.3 to 3.0 times greater on NW sites. Ground spread indices and D.M. yields showed a response to the higher rate of fertiliser on some sites only. Higher air and soil temperatures on NW aspect, particularly in early spring and in autumn favoured a longer period of growth compared with E.S.E.

The trials showed that Maku lotus could be a valuable herbage resource on warmer northerly aspects above 1000 m. In addition, the high variability amongst lotus plants suggested that production for such cool environments could be improved by selection within existing populations.

Keywords: Maku lotus, *Lotus pendunculatus,* aspect, high altitude, persistence, plant performance, plant selection.

INTRODUCTION

The place of Grasslands Maku lotus *(Lotus peduncuIatus* Cav.) as a potential contributor to production in the tussock grasslands has been investigated in considerable depth over the last 10-12 years. In the southern half of South Island, scientists based on Invermay Agricultural Research Centre have shown its potential on soils with a pH less than 5.2, where it can outyield white clover at equivalent rates of applied phosphorus (Lowther, 1977; Scott and Mills, 1981). However, the plant has given a reduced performance in competition with white clover or a dense grass sward, both in rate of seedling development and in herbage production, particularly where the soil pH is above 5.6 (Brock and Charlton, 1978; Sheath, 1981). Although some of the earliest field research reported with Maku lotus was in the revegetation of exposed subsoils in Canterbury and North Island at altitudes in excess of 1,000 metres (Nordmeyer & Davis, 1977), most of the experiments in the south have been conducted at altitudes of less than 1,000 metres. Cossens (1983) concluded generally that Maku lotus should be looked upon as a pioneer legume for soils where pH is less than 5.0 at altitudes from 300-900 m. Although Cossens reported high yields from Maku at 1,500 m in the Awatere valley of Marlborough, he considered that it was unclear how long these high yields would persist under grazing when subjected to low temperatures or increasing grass competition as soil nitrogen level built up.

There are extensive areas of steep mountain slopes, particularly in Canterbury and Marlborough above 1,000 m where pH of the top soil or the exposed subsoil is above 5.0 (Dunbar and Adams, 1972), but where there are negligible amounts of white clover. In the zone from about 900 m to 1,500 m vegetation is generally sparse. Much of this zone is used for late summer/early autumn grazing, although not always every year.

Although Maku lotus appeared to have potential for both grazing use and soil conservation in this zone, it was not clear whether the cultivar would persist and spread at this altitude under low fertiliser inputs. Further it was not known what density of plant establishment would be necessary to provide effectiveoccupation of ground surface in a four to five year term, or how aspect would influence these factors. It was to provide some answers to these questions that the lotus trials at the Grampian Mountains sites were begun in 1980.

MATERIALS & METHODS

Study Area

The study area is at 1,460 m on the north side of the Grampian Mountains in inland South Canterbury. It contains slopes of 25-30° on contrasting north west (319" True) and east-south-east (119° True) aspects, close to a ridge crest. The NW aspect vegetation is dominantly snowgrass (*Chionochloa rigida*) and spaniard (*Aciphylla aurea*). The ESE aspect also has snowgrass (mainly *C. macra*), and Spaniard, but has a high proportion of blue tussock (*Poa colensoi*) and hard tussock (*Festuca novae-zelandiae*). Sheep have been excluded since 1977 on NW, and 1978 on ESE aspect.

Soils are high country yellow-brown earths, mapped as Benmore steepland soils. The area has not been oversown or topdressed prior to this study, and soil tests (0-15 cm) showed a range of pH from 5.2-5.5, and Olsen P from 7-12, with no clear differences between aspects.

Climate Records

Records of precipitation were kept on an approximate four week basis, using a standard manual meteorological rain gauge adapted to allow additional water storage. Air temperatures at 1 m above ground level within a small Stevenson screen, and soil temperatures at 10 cm beneath a bare soil surface were recorded on 31 day thermographs for both aspects. No climate records were kept for the period 10 May-13 October, 1983.

Treatments and Layout

"Grasslands Maku" lotus plants were grown from seed in two types of propagation tubes at Lincoln from October 1979 until field transfer on 15 and 16 October 1980. Top growth was removed twice during this period. Types of propagation tube were a "root-trainer" tube with 40 ml volume and a simple cylindrical tube with 85 ml volume.

Field treatments consisted of plants from these two types of propagation tubes, and fertiliser (20% sulphur enriched superphosphate) at two rates, 100 kg/ha (F100) and 300 kg/ha (F300), applied once only at seven weeks after transplanting. Tube type and fertiliser rate treatments were applied in a 2 x 2 factorial layout with three replications at each of five trial sites. Two sites were on NW aspect and three on ESE. Each contained 192 plants placed in a 12 x 16 grid pattern, with equal spacings between plants within a site. NW trial sites had spacings of 1 m and 2 m (West 1 m and West 2 m), while ESE trial sites had spacings of 0.5 m, 1 m and 2 m (East 0.5 m, East 1 m, and East 2 m). Total ground areas encompassed within the sites were thus 48 m^2, 192 m^2 and 768 m^2 for 0.5 m, 1 m and 2 m spacings respectively, and at these spacings individual lotus plants in theory had areas of 2,500 cm', 10,000 cm^2 and 40,000 cm^2 available for spread.

There was a large difference between NW and ESE aspect sites in density of resident vegetation. There was a lesser but marked difference in vegetation density between East 2 m and the two other sites on ESE aspect. Estimates of living vegetation at ground surface level on a scale of O-10 within a 50 cm x 50 cm sample area surrounding each lotus planting position, gave sites values as follows:

	West 1 m	West 2 m	East 0.5 m	East 1 m	East 2 m
Mean	2.14	2.36	8.44	8.52	7.11
S.D.	1.46	1.39	0.76	0.69	1.98

Plant Records

In April 1981 after the first summer lotus plants were scored for survival and vigour, and subsequently in February of 1982, 1983 and 1984 surviving plants were measured at the ground surface for maximum spread both across and up and down the hill slope. These dimensions were multiplied together to give an index of area of ground spread for each plant. In the 1983-84 season, additional such measurements were made in November at West 1 m and East 1 m, and at all sites in December. After measurement in February 1984 plants in West 1 m and East 1 m were individually harvested for DM yield determination, while plants in West 2 m and East 2 m were harvested after measurement in March.

RESULTS AND DISCUSSION

Climate

Mean annual precipitation for the first two years of the trial was approximately 780 mm compared with a six year mean (15 December 1976 to 20 December 1982), of 912 mm. Records for the four, September-March growing seasons from 1980-1984 averaged 360 mm, with the first season below, and the final season much above this figure. The comparable figure for the longer 1976-1982 period was 400 mm.

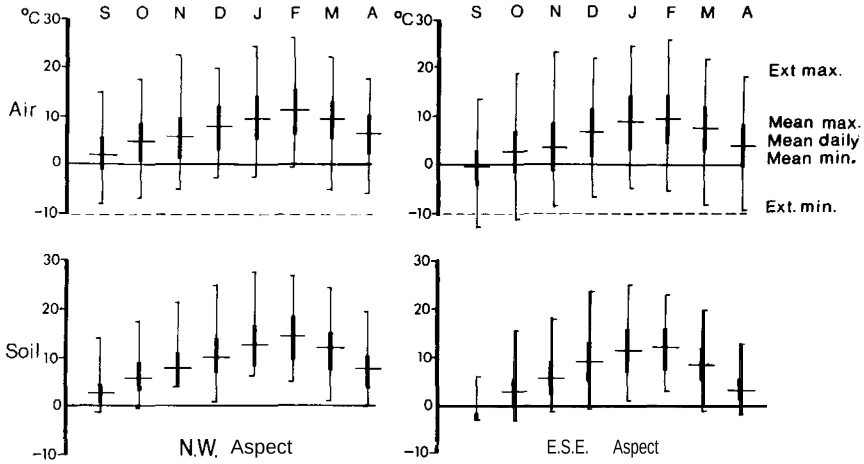

Figure 1: Air temperatures (+ 1 m) and soil temperatures (-10 cm, bare soil) recorded at 1460 m on Grampian Mountains for September-April *1980-81 to 7983-84.*

The air and soil temperature regime of the September-April seasons from 1980 to 1984 is summarised in Figure 1. Temperature differences between aspects were greater at the beginning and end of the season than in mid-season. In September, NW mean air temperature was 2.3" above the mean for ESE. In January, NW was only 0.9°C higher, but by April it was 2.2" above ESE. Soil temperature differences were much larger. In September, NW aspect mean soil temperature was 4.4°C above ESE, and in April 3.8". In the 1983-84 season, both mid-spring and late autumn mean temperatures were approximately 2" warmer than average, while mid-summer temperatures were lower than average. Air temperatures of 0°C or below were recorded less frequently on NW than on ESE (Table 1), although even on NW there were only two months (February) free of screen frosts during the four seasons. By contrast, soil temperatures seldom fell below 0” on either aspect during December-March.

Records for the May-August period showed that on NW aspect soil temperatures usually remained below or near freezing from late May/early June until late August/early September. The corresponding period for ESE aspect was up to two months longer, that is from late April/early May until late September/mid-October.

Table 1: DAYS WITH MINIMUM TEMPERATURE AT OR BELOW 0°C (Mean for 1980-84 seasons)

		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Screen Air	NW	22.3	12.5	12.7	7.5	4.0	1.3	4.0	9.5
(1 m)	ESE	25.0	17.0	16.3	12.5	10.0	4.2	7.0	17.0
Soil	NW	19.3	3.7	0.5	0.0	0.0	0.0	0.0	0.2
(10 cm)	ESE	30.0	16.2	6.0	0.2	0.0	0.0	0.7	10.5

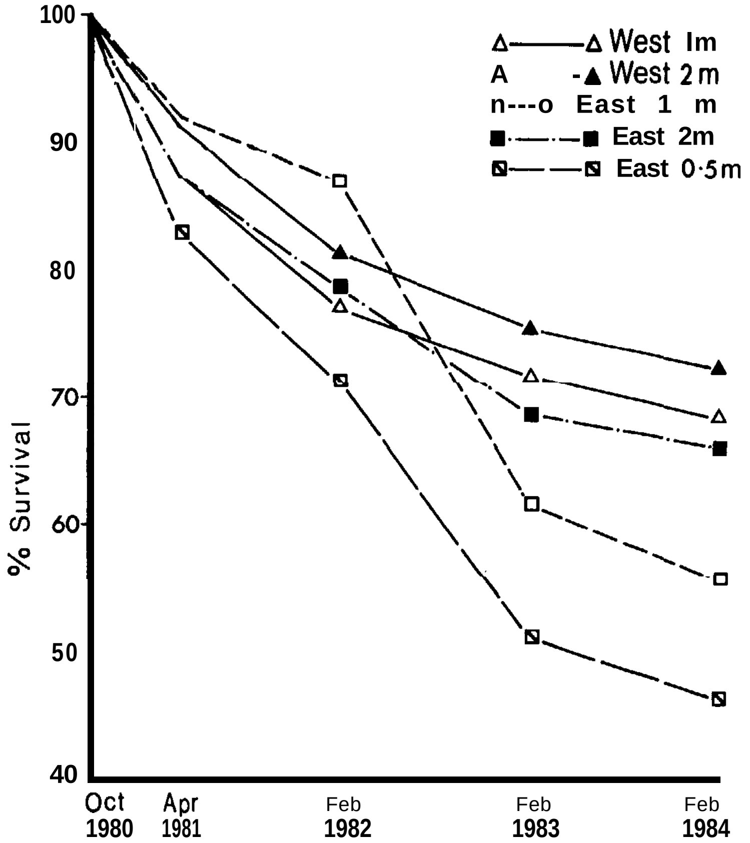

Figure 2: Survival (%) of Maku lotus plants at five sites on Grampian Mountains, from 1980 to 1984.

Plant Survival

In 1984, at the end of the fourth growing season, lotus plant survival ranged from 72.4 percent at West 2 m site to 46.3 percent at East 0.5 m (Figure 2). Chi square analysis of the counts showed that significant differences between survivals for sites did not appear until February 1983 (X^2 11.0, df4). Survivals in West sites were then significantly higher than for East sites (X^2 6.18 dfl), and this situation remained in 1984. However, within this general situation there were very small differences between survival at the East 2 m site and the two West sites, but larger, significant differences between survival at East 2 m and at the other two less successful East sites (X^2 5.56, dfl). This indicates that the temperature differences between the two aspects may not on its own have had major effect on transplant survival. Although Musgrave (1977) reported severe winter mortality of lotus seedlings on a shady aspect, his seedlings had developed from seed sown on cultivated ground where there was little resistance to frost heave. At the East 1 m and 0.5 m Grampian sites, most transplants were amongst dense tussock which provided protection from frost heave, but also provided competition for establishment and survival. This competition may have been the major factor leading to higher mortality on East 0.5 m and 1 m sites than on East 2 m. At no stage were there significant differences in survival between East 0.5 m and 1 m sites.

The rate of fertiliser did not consistently or significantly affect survival in the first or following season, either within sites or over the trial as a whole. Similarly the type of propagation tube did not produce consistent or significant differences.

Plant growth

Growth of lotus plants was extremely variable, and therefore the influence of aspect, site and treatment on ground spread indices and DM yield was assessed by using data for all surviving individuals in the comparisons, rather than by using treatment and block means.

On West sites, mean ground spread indices were much larger than for East sites. Trends between sites were similar from 1982 to 1984 (Table 2).

Table 2: LOTUS GROUND SPREAD INDICES (cm^2/plant), 1982-84

Site	Feb 82	Feb a3	Feb 84	Mar 84
West 1 m	1054	1011	1390	.[1]
West 2 m	991	984	1452	2277
Signif.	n.s	n.s	n.s	
LSD < 0.05	242	239	331	
Pooled S.D.	1000	1000	1371	
East 0.5 m	82	106	192	296
East 1 m	152	157	313	.[1]
East 2 m	314	377	690	1214
Signif.	***	• [illegible]	***	• [illegible]
LSD < 0.05	67	112	189	312
Pooled S.D.	200	343	585	1000

[1] Plants harvested in February

There were much larger differences between mean ground spread indices for the East sites than between West sites and it is probable that these differences, like those for survival rates, are related to differences in type and density of native vegetation present. There was no evidence that the lotus ground spread was influenced by the particular transplant spacing for a site. Absence of inter-plant competition by lotus is indicated by comparing the mean ground spread indices in

Table 2 with the available areas for the different spacings. Thus the February 1984 mean indices for West 1 m, West 2 m, East 0.5 m, East 1 m and East 2 m represent 13.9, 3.6, 7.7, 3.1 and 1.7 percent only, of the respective areas available for individual spread. Even at the later March measurement for East 0.5 m spacing, the mean ground spread index represented less than 12 percent of the area available for each plant.

Total lotus ground cover at each trial site was affected by numbers of transplants surviving as well as by the mean ground spread index. The graphical representation of the combined effect (Figure 3), further demonstrates the superiority of West sites for total lotus growth. The large extension of growth into mid-March shown for the favourable 1983-84 season, is in accord with growth descriptions given by Sheath (1981).

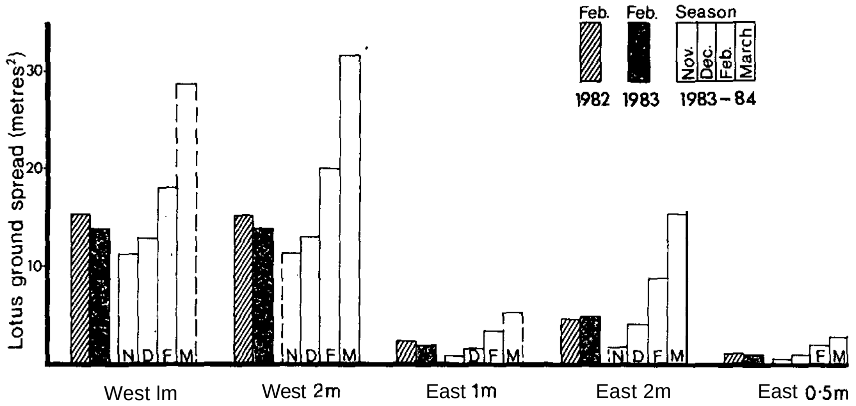

Figure 3: Total lotus ground spread (sum of indices) at five sites on Grampian Mountains during three successive growing seasons 1982-1984 inclusive (dotted line = spread inferred).

Significantly higher lotus vigour scores for the F300 fertiliser rate compared with the F100 rate were recorded at three sites by April 1981 (West 2 m, East 0.5 m, East 2 m). Although larger mean ground spread indices were recorded for F300 than for F100 at all sites in the three seasons 1981-82 to 198384, the February 1984 records show that the difference within sites was significant at West 2 m and East 0.5 m only (Table 3). For all plants surviving on each aspect as a whole, however, the F300 rate coincided with significantly larger mean ground spread indices.

Individual plant DM yields from West 1 m and East 1 m in February 1984, and from West 2 m and East 2 m in March (Table 4), supported the results obtained from

Table 3: LOTUS GROUND SPREAD INDICES (cm^2/plant), FEBRUARY 1984.

	NW Aspect			ESE Aspect			
	West I m.	West 2 m.	Aspect Mean	East 0.5 m.	East I m.	East 2 m.	Aspect Mean
F100	1372	1136	1249	140	291	586	363
F300	1409	1802	1608	255	340	807	506
Signif.	n.s.	*	•	*	n.s.	n.s.	•
Pooled S.D.	1184	1498	1359	244	371	838	618
Site Mean	1390	1452	1422	192	313	690	429

plant spread measurements. At each harvest, dry weight and ground spread index for each plant were closely correlated.

Comparison of plants from the two aspects in February is, of course biased by the effect of a later start to growth on ESE aspect. For example, on 13 October 1983 only 23 percent of lotus plants on the East 1 m site had commenced growth, compared with 83 percent on West 1 m. By 14 November the respective tallies were 78 and 96 percent. The opportunity for plants on ESE aspect to grow into the autumn and as it were “catch up” on NW plants may be severely limited by the frequency and severity of frost in March (Table 1 and Figure 1). In a favourable season such as 1983-84 growth can continue longer with consequent additional benefit to plants on the colder aspect. Thus from mid-February to mid-March 1984, the mean ground spread index for lotus on East 2 m site increased by 76 percent, compared with a 57 percent increase for plants on West 2 m. Proportionately similar increases in ground spread and yields could have been expected from East 1 m and West 1 m if plants had been left uncut until March.

Table 4: LOTUS DRY MATTER YIELD (grams/plant), 1984.

	February 1994		March 1984	
	West 1 m	East 1 m	West 2 m	East 2 m
F100	6.74	2.18	i0.28	8.13
F300	6.45	2.18	22.09	15.96
Signif.	n.s.	n.s.	**	•
Pooled SD.	7.10	3.26	22.85	20.00
Site Mean	6.59	2.18	15.85	11.83
Signif.	•		n.s.	
Pooled S.D.	5.67		21.33	

CONCLUSIONS

The Grampians study has shown a high degree of persistence by ungrazed Maku lotus plants established from transplants at 1460 m altitude, but also some apparent susceptibility to competition from dense tussock ground cover. The colder temperatures of the shadier aspect may not have been critical on their own to survival of larger lotus plants, but there would undoubtedly be severe disadvantage to establishment from seed, and on colder or more densely vegetated slopes than the Grampian sites, plant establishment could be negligible.

The marginal character of the environment for herbage production is indicated, especially on shady slopes. The mean ground spread index for lotus plants measured at the end of the fourth growing season suggests that with an establishment of four to five plants per m^2 as an optimum, competition amongst lotus plants would be unlikely on aspects and altitudes similar to these sites. At a density of five plants/m^2, the mean plant production measured in March from West 2 m site translates to about 500 kg/ha at the lower rate of superphosphate, and about 1000 kg/ha at the higher rate. At the same plant density lotus production from the East 2 m site would be equivalent to about 400 and 800 kg/ha respectively for the two fertiliser rates. Production might be considerably less in years when freezing conditions occurred early in the autumn, and on colder or more densely vegetated slopes.

On country above 1000 m which has a relatively short season of grazing use in late summer and autumn, and particularly on the warmer NW to NE aspects with less dense snowgrass populations, the establishment of Maku lotus could provide a valuable resource. However, the wide variation in individual plant performance within sites in this study suggests also that there is potential for selection within such populations for plant material with high performance under the cool climate prevailing.

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