Responses of caucasian clover to sulphur fertiliser

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Abstract

Sulphur responses by caucasian clover (*Trifolium ambiguum*) were investigated on a sulphur (S) deficient high country site where 4-year-old plants were showing S deficiency. Clover responses from a December harvest were maximum at 40 kg S/ha, but foliar S values remained low at 0.12% and did not increase at the 80 kg S/ha rate. Foliar and soil P values were also low. Foliar analyses of caucasian and white clover samples from another high country site and two fertile lowland sites showed that the two species differ only in their Na and K contents with white clover having higher values than caucasian clover.

Keywords: caucasian clover, foliar analysis, foliar Na levels, natrophobe, sulphur response, *Trifolium ambiguum*, white clover

Introduction

Much of the hill and high country pasture in New Zealand requires regular inputs of phosphatic, sulphur and molybdic fertilisers to maintain the productivity of oversown legumes. Some species, such as white clover (*Trifolium repens*), become minor components of pastures unless regular topdressings of these fertilisers take place. Other legumes have the potential to remain productive in the pasture longer than white clover with less regular fertiliser applications on account of a variety of morphological and/or physiological features. Thus the perennial Russell lupin, *Lupinus polyphyllus*, has a large tap-root and an apparent phosphorus (P) efficiency mechanism (White *et al.* 1995), Maku lotus, *Lotus pedunculatus*, has a tap-root and short rhizomes (Sheath 1980) and a high P uptake efficiency (Kee 1981), while caucasian clover, *Trifolium ambiguum*, has a combination of a large tap-root with widely spreading rhizomes and a potential ability to store nutrients in its underground biomass (Strachan *et al.* 1994).

In a fertiliser trial at Mesopotamia station, using perennial lupin, White *et al.* (1995) showed that, in the first 3 years after sowing, lupin responded to P fertiliser only in the presence of sulphur (S) fertiliser. By the fourth year after sowing, lupin production declined. Chemical analysis indicated the lupin was S deficient. Production was boosted on application of 60 kg S/ha as gypsum at all rates of P from zero to 50 kg P/ha. Moorhead *et al.* (1994) showed, in a trial sown adjacent to the lupin trial, that the establishment and growth of caucasian clover in the first two years was enhanced when the seed was sown in the soil rather than broadcast and when 300 kg/ha of sulphur superphosphate fertiliser was used rather than 150 kg/ha. Subsequent clover growth displayed increasing S deficiency symptoms.

This paper presents results on the growth of caucasian clover using that earlier establishment experiment, after topdressing with S fertiliser, 4 years after establishment. In addition foliar analyses of the caucasian clover from this experiment are presented, along with comparative data for foliar analyses of caucasian clover and white clover from three other sites. This was done to investigate whether caucasian clover differs from white clover in the mineral composition of its foliage.

Methods

A field experiment was established in spring 1992, at Mesopotamia Station, South Canterbury, New Zealand on a yellow-brown earth, pH of 5.3, P retention of 44% and deficient in S (S = 2ppm as SO_4), P (Olsen P = 6), molybdenum and boron. The site is 500 m above sea level, has rainfall of 940 mm per annum and has cold winters with little or no pasture production for up to 5 months.

Caucasian clover (*Trifolium ambiguum* cv. Monaro) seed was sown on 1 October 1992 into depleted fescue tussock (*Festuca novae-zealandiae*) dominated by very low-producing browntop (*Agrostis capillaris*) and sweet vernal (*Anthoxanthum odoratum*) grasses and herbs such as hieracium (*Hieracium pilosella*). The trial was a balanced, incomplete block with plots consisting of paired comparisons of all treatments. There were three establishment methods (strip seeding and sod seeding – placed the seed and fertiliser in the ground in double rows, and broadcast – allowed the seed and fertiliser to fall on the surface of the soil in 200 mm bands) and two levels of fertiliser were applied as either 150 or 300 kg/ha of molybdic sulphur superphosphate (8%P, 20%S). The six treatments were compared in all combinations in doubled, paired rows (designated plots), 20 m long, with 1 m between plots. There were five paired rows of each treatment per block and two replicates of each block giving a total of 30 plots. Full details of the trial and sowing procedure are presented by Moorhead *et al.* (1994).

In October 1996, a further 0, 20, 40 or 80 kg S/ha, as gypsum, was applied as 5 × 1 m sub-plot treatments to a quarter of each of the original 30 main plots. The trial was grazed each year by sheep after the early summer (December) sampling and again in winter before spring growth.

On 3 December 1997, yields of clover, grasses and dead material were obtained by cutting two 0.2 m^2 quadrats to 20 mm stubble height from each sub-plot. Twenty leaves plus petioles of caucasian clover for mineral analyses were also plucked on 3 December 1997 from the S sub-plots.

In March 1998, leaf plus petiole samples from the small number of isolated white clover plants which had ingressed into the plots were sampled for mineral analysis along with caucasian clover leaves growing adjacent to these plants. Ten soil cores, 15 cm deep, were taken for mineral analysis in March 1998 from each of the eight S sub-plots containing only the broadcast establishment treatments (Table 1).

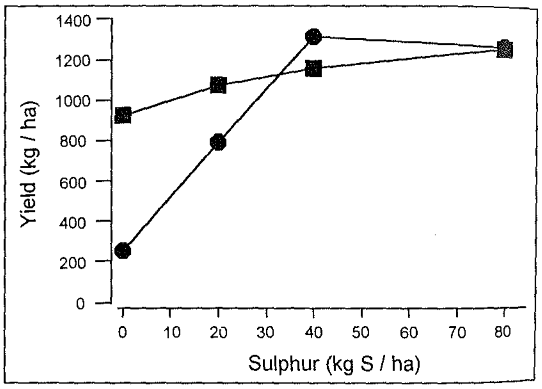
As this trial was sown only in caucasian clover, a replicated comparison of caucasian clover with white clover was not possible. Additional comparisons were obtained from three other sites. Leaf plus petiole samples of caucasian and white clovers, as well as soil samples, were taken in March 1998 from another trial on a "top" terrace at 700 m a.s.l. at Mesopotamia Station and two lowland experiments established at Lincoln University. The trial at Mesopotamia was sown in 1975 (Lucas *et al.* 1980) and small areas received a recent fertiliser application of 500 kg/ha S superphosphate in 1996 before this sampling. The trials at Lincoln University were sown on a Wakanui silt loam (Webb 1996) and a Templeton silt loam (Black pers. com. 1998), with soil tests showing both to have moderate to good fertility (Table 1). The first of these experiments was designed to investigate the "sociability" of the two clovers with five grass species, while the second was designed to measure sheep liveweight gain from grazing the two clovers when each was sown with Ruanui perennial ryegrass (*Lolium perenne*) with two levels of fertility.

Results

Five years after establishment there was a slight residual effect of sowing method on early December 1997 yields of causasian clover, with the strip and sod seeding yielding 14 and 10% more (960 and 920 kg DM/ha) respectively than the broadcast 830 kg DM/ha ($P<0.017$). Clover content was approximately 30% of the total spring production irrespective of establishment sowing method or initial fertiliser treatment. The rhizomes of the caucasian clover had spread laterally throughout the 1 m space between all plots. There was no difference between the two rates of establishment fertiliser on clover yields nor total DM yields 5 years after sowing.

Caucasian clover yields responded to the addition of S (Figure 1), increasing from 250 kg DM/ha in the zero S treatment to reach a maximum of 1320 kg DM/ha with 40 kg S/ha. There was no further increase in yield as the S fertiliser level was raised to 80 kg S/ha. Grass yields increased from 920 to 1250 kg DM/ha over the range of S fertiliser levels (Figure 1). This corresponds to total yields of dry matter in each sub-plot S treatment ranging from 1950 to 3400 kg DM/ha, the balance of the dry matter comprising weeds and dead material. The percentage of weeds in each treatment was approximately 5–7%, and the percentage of dead material decreased from 34% in the zero S treatment to 20% with the 80 kg S/ha treatment.

Figure 1 Effect of sub-plot S (kg S /ha) on caucasian clover and grass yield (kg/ha). SED clover and grass = 130 kg/ha. ■ = grass; ● = caucasian clover



Foliar analyses of caucasian clover (Table 2) indicated that, although the N and S percentage increased with the S applied in October 1996, the values were low, with N values of 1.97–2.54% and S values of 0.08–0.12%. P values were also very low and K marginally deficient. Values for P, Mg, and Ca all decreased with higher levels of applied S.

The March 1998, chemical analyses of the leaves and petioles of both caucasian and white clovers from the sub-plot trial, showed similar levels of all nutrients in each species (Table 2). Values for N, P, S and K were all considerably higher than in the December harvest.

Table 1 Chemical analyses of soil in the Mesopotamia S sub-plot, (low fertility), the Mesopotamia medium fertility "top terrace", the Lincoln sociability and Lincoln grazing experiments. Data are presented as MAF quick test units. (Cornforth & Sinclair 1984)

	Soil analyses (MAF Quick test units)						
Site	pH	P	Mg	Ca	K	Na	S
Mesopotamia low fert – outside	5.3	5	23	6	5	2	2
Mesopotamia low fert – inside	5.3	6	22	6	6	2	*
Mesopotamia med. fert	5.2	6	11	6	5	3	14
Lincoln – sociability	6.2	44	49	11	31	12	9
Lincoln – grazing	6.2	16	25	10	14	11	11

* = S levels in the S superphosphate-treated plots: 3, 4, 7, 8 ppm in the plots with zero, 20, 40 and 80 kg/ha S superphosphate. MAF quick test units = ppm for SO_4 –S.

Table 2 Comparison of leaf chemical analysis of caucasian (Cc) and white (Wc) clover in relation to S fertiliser and contrasting fertility sites.

Site, date & species	Leaf analysis (% DM)						
	N	P	S	Mg	Ca	K	Na
Mesopotamia low fert., December							
0 kg S/ha	1.97	0.13	0.08	0.30	1.85	2.15	
20 "	2.33	0.11	0.11	0.25	1.69	2.18	
40 "	2.38	0.11	0.12	0.23	1.60	2.13	
80 "	2.54	0.11	0.12	0.22	1.45	2.16	
Mesopotamia low fert., March							
Cc.	3.64	0.23	0.18	0.30	1.55	2.90	0.02
Wc	3.42	0.21	0.19	0.32	1.63	3.16	0.04
Mesopotamia med. fert., March							
Cc.	3.61	0.28	0.18	0.30	1.64	2.48	0.02
Wc	3.93	0.29	0.20	0.28	1.45	2.84	0.07
Lincoln sociability trial							
Cc.	4.01	0.42	0.23	0.27	1.29	4.38	0.02
Wc	3.87	0.36	0.24	0.29	1.15	5.24	0.22
Lincoln grazing trial							
Cc.	3.95	0.29	0.22	0.36	1.72	2.14	0.02
Wc	3.91	0.30	0.24	0.28	1.43	2.70	0.40

The Mg, Ca and K values appear satisfactory, while both P and S values appear low at 0.23/0.21% and 0.18/0.19% respectively. Foliar analysis values of samples collected in March 1998, from the medium fertility, top-terrace at Mesopotamia are very similar to those from the S sub-plots, harvested in March except the P levels were higher at 0.28/0.29% in the fertilised 'top terrace' samples.

Compared with the leaf material from the high-fertility sites at Lincoln (Table 2), the material from the Mesopotamia sites in March 1998 showed similar values for N, Mg, Ca and K except in the grass sociability experiment at Lincoln where the K values were considerably higher. Values for leaf P and S at Mesopotamia were lower than those at Lincoln. The only major differences in foliar analyses between caucasian and white clovers occurred with Na and K. Sodium was much higher in white than caucasian clover on the fertile Lincoln sites and marginally higher at the Mesopotamia sites while K was higher in white clover at all sites.

Chemical analyses of the soils from the broadcast sub-plots and the top terrace were similar to those in the unimproved areas outside the plot area of the S rates experiment at Mesopotamia (Table 1) except where S had been added. Values for S were 2 ppm in the unimproved soil outside the sub-plot area but 3, 4, 7 and 8 ppm inside the zero, 20, 40 and 80 kg S/ha treated sub-plots respectively. The value for S on the recently fertilised, top terrace was 14 ppm, and analyses of the soils at Lincoln confirmed their higher overall fertility (Table 1).

Discussion

Although Moorhead *et al.* (1994) demonstrated a response to the higher establishment fertiliser rate in the first 2 years of the trial at Mesopotamia, the effect of this fertiliser was no longer obvious on DM production of the clover and total DM production of the sward or the foliar analyses after 5 years, even though 150 and 300 kg/ha S superphosphate had been placed immediately under the seed. Moorhead *et al.* (1994) also demonstrated a major effect of sowing method on the initial establishment, but the results indicated after 5 years this difference was slight and the caucasian clover sown by broadcasting had spread over a similar area to the plants established from drilling.

In 1996, before the sub-plot S treatments were applied, visual symptoms indicated that S deficiencies and or slow inoculation of the new daughter plants was occurring. Foliar analyses, averaging 0.10% S, supported the diagnosis of S deficiency at that time.

The S sub-plot treatments increased the spring yield of caucasian clover 5-fold, from 250 to 1300 kg DM/ha. Production from unimproved grassland outside the plots was less than 500 kg DM/ha/year. While there was a low yield of clover in the zero S sub-plot treatment, the grass component had presumably benefited from the N transfer that occurred from the clover to the grass in the early years of the trial when the clover was fixing N by using the fertiliser applied at establishment. In the absence of the additional S, the grass yield at 950 kg DM/ha was 70% of the maximum yield achieved at 80 kg S/ha, which indicates that the S-deficient clover could not compete with the vigorous growth of the browntop with its fine root system and its ability to take up the scarce nutrients from the soil (Caradus 1980; Harris 1973; Jackman & Mouat 1973; Mouat 1983).

Clover yield increased to reach maximum production at 40 kg S/ha and the yield was not increased with 80 kg S/ha. This would suggest that the critical value for S in caucasian clover would be about 0.12% reached with the 40 kg S/ha. However, the value of 0.12% is generally considered to indicate deficiency (McNaught 1970), and this is likely given the marginal soil S values of 7 ppm S as SO_4 in the 40 kg S/ha sub-plots. This low S content is paralleled by the low N concentration of about 2.4%. An alternative explanation may be that S was not alone in limiting growth, as the low P values in the herbage (0.11%) and in the soil (Olsen P of 6) indicate that, by this fifth year after sowing, P is probably also limiting yield and N fixation. No other macro-nutrient appears low enough to cause a major depression in yield.

In spite of the depression in yield at the zero S rate, the caucasian clover was still present in the sward in spite of competition with browntop. Although white clover was not sown in this trial, and there is no direct comparison between clover species, experience at Mesopotamia (Lucas *et al.* 1980; Kee 1981) indicates that white clover would not have persisted as long under such conditions in the absence of additional fertiliser. This may be related to the large tap-root and rhizome system that is capable of storing nutrients in caucasian clover (Strachan *et al.* 1994).

Results of mineral analyses for N, P and S from the December harvest from Mesopotamia are lower than those from the March harvest. It is considered unlikely that this is owing to error in the laboratory analysis procedure, even though samples were analysed on different dates, because some samples from the Lincoln grazing experiment were included at each date. The difference may be a function of age of the leaves or the rate of growth in the drier January/February period.

Concentrations for most elements were similar for both causasian and white clovers over a range of edaphic conditions. There were, however, differences in the concentrations for the monovalent cations, Na and K, with values higher in white than caucasian clover. Jackman (1960) suggested a correlation between cation exchange capacity (CEC) and monovalent cation uptake. Plants with lower CEC took up more monovalent cations than plants with higher CEC. While he reported values for white clover there do not appear to be any published CEC values for caucasian clover to determine whether this relationship holds for these two species.

Differences in Na levels between the two clovers were particularly marked at the Lincoln sites, where caucasian clover had only 0.02% Na while white clover had 0.22 and 0.40%. Even at the Mesopotamia sites there was more Na in the white clover (0.04%) compared with the caucasian clover (0.02%). This reflects the availability of the Na in the soil at the lowland Lincoln sites (soil Na = 12 ppm) which are located only a few kilometres from the sea and the very low values (soil Na = 2 ppm) at the inland high country site at Mesopotamia. Adequate levels for Na in herbage for finishing sheep are quoted by Cornforth & Sinclair (1984) as 0.09%, which implies that caucasian clover at both sites, and white clover at Mesopotamia, have inadequate Na levels for animal production. It would appear that caucasian clover should be classified as a low Na (natrophobic) species (Smith *et al.* 1978), along with other pasture legumes like lucerne, red clover and lupin (Grace 1983), and white clover should be classified as a high Na (natrophilic) species.

In conclusion, caucasian clover needs S as well as P fertilisers if it is to be maintained in a productive state. Caucasian clover is a natrophobe compared with white clover which is a natrophile. Apart from the differences in Na and K concentrations, there are few differences between caucasian and white clovers in their foliar mineral concentrations, but the greater ability of caucasian clover to persist in hill and high country swards may be due its ability to store nutrients in its rhizome and root mass.

REFERENCES

Caradus, J.R. 1980. Distinguishing between grass and legume species for efficiency of phosphorus use. *New Zealand journal of agricultural research 23*: 75–82.

Cornforth, I.S.; Sinclair A.G. 1984. Fertiliser and lime recommendations for pastures and crops in New Zealand. Second revised edition. Wellington: Ministry of Agriculture and Fisheries.

Grace, N.D. 1983. The mineral requirements of grazing ruminants. *New Zealand Society of Animal Production,* Occasional publication No 9.

Harris, W. 1973. Why browntop is bent on creeping. *Proceedings of the New Zealand Grassland Association 35:* 101–109.

Jackman, R.H. 1960. Competition between pasture species for nutrients from the soil *Sheepfarming Annual:* 75–84.

Jackman, R.H.; Mouat M.C.H. 1973. Browntop and pasture nutrition. *Proceedings of the New Zealand Grassland Association 35*: 95–100.

Kee, K.K. 1981. Phosphate response and uptake by *Lotus pedunculatus* (cv. Grasslands Maku), *Trifolium repens* (cv. Grasslands Huia) and *Trifolium ambiguum* (cv. Prairie). PhD thesis, Lincoln College.

Lucas, R.J.; White, J.G.H.; Daly, G.T.; Jarvis, P.; Meijer, G. 1980. Lotus, white clover and caucasian clover oversowing, Mesopotamia Station, South Canterbury. *Proceedings of the New Zealand Grassland Association 42*: 142–151.

McNaught, K.J. 1970. Diagnosis of mineral deficiencies in grass-legume pastures by plant analysis. *Proceedings of the International Grasslands Congress 11:* 334–338.

Moorhead, A.J.E.; White, J.G.H.; Jarvis, P.; Lucas, R.J.; Sedcole, J.R. 1994. Effect of sowing method and fertiliser application on the establishment of caucasian clover. *Proceedings of the New Zealand Grassland Association 56*: 91–95.

Mouat, M.C.H. 1983. Phosphate uptake from extended soil solutions by pasture plants. *New Zealand journal of agricultural research 26*: 75–82.

Sheath, G.W. 1980. *Lotus pedunculatus* – an agricultural plant? *Proceedings of the New Zealand Grassland Association 42*: 160–168.

Smith,G.S.; Middleton, K.R.; Edmonds, A.S. 1978. A classification of pastures and fodder plants according to their ability to translocate sodium from their roots to aerial parts. *New Zealand journal of experimental agriculture 6*: 183–188.

Strachan, D.E.; Nordmeyer, A.H.; White, J.G.H. 1994. Nutrient storage in roots and rhizomes of hexaploid caucasian clover. *Proceedings of the New Zealand Grassland Association 56*: 97–99.

Webb, A.M.C. 1996. Competitive ability of caucasian clover (*Trifolium ambiguum*) compared with white clover (*Trifolium repens*) on lowland and high country sites. BAgrSci (Hons) dissertation. Lincoln University.

White, J.G.H.; Jarvis, P.; Lucas, R.J. 1995. Fertiliser requirements of Russell lupins. *Proceedings of the Agronomy Society of New Zealand 25*: 87–90.