Caucasian clover was more productive than white clover in grass mixtures under drought conditions

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Abstract

This experiment compared the productivity of caucasian or white clover when established with five perennial grass species over 6 years in a dry lowland environment. Hexaploid 'Endura' caucasian clover or 'Grasslands Demand' white clover were sown in December 1994 with high endophyte 'Yatsyn' perennial ryegrass, 'Grasslands Wana' cocksfoot, 'Grasslands Advance' tall fescue, 'Grasslands Gala' grazing brome, or 'Grasslands Maru' phalaris into a deep, fertile silt loam. Initial establishment of clovers was poor with ryegrass and grazing brome. Some volunteer white clover established in all 10 treatments. After the first 14 months, no irrigation was applied over the following 4 years. Sheep grazed plots about six times each year. The legume cover in 15-month-old pastures was higher when sown with white clover (29%) than caucasian clover (21%) but dry conditions during 1997/1998 (60% of 680 mm mean annual rainfall) and 1998/1999 (66% of mean rainfall) decreased the percentage of legume in white clover pastures. In February 1998 and March 1999, legume contributed 37% and 21% of the dry matter (DM) in caucasian clover pastures, but only 4% and 1% in pastures sown with white clover. Rainfall during the sixth season (1999/2000) was more favourable (111% of mean rainfall). Total DM production from July 1999 to June 2000 was 10.0 t DM/ha from caucasian clover pastures and 8.7 t DM/ha from pastures sown with white clover. The mean proportion of legume in white clover pastures ranged from 9% when sown with ryegrass and phalaris to 1% with cocksfoot. In contrast, mean caucasian clover legume contents were similar across all grass treatments at 20%, but reached 46% with cocksfoot during summer. It was concluded that caucasian clover is more tolerant of summer moisture stress than white clover when in association with perennial grass species.

Keywords: botanical composition, *Bromus stamineus*, *Dactylis glomerata*, legume content, *Lolium perenne*, moisture stress, pasture production, *Phalaris aquatica*, *Schedonorus phoenix* syn. *Festuca arundinacea*, *Trifolium ambiguum*, *T. repens*

Introduction

Caucasian clover (*Trifolium ambiguum*) is well adapted to fertile South Island rangeland (Woodman *et al.* 1992; Allan & Keoghan 1994; Scott 1998) and may prove valuable in lowland intensive farming systems where white clover (*Trifolium repens*) suffers abiotic and/or biotic stress. For instance, on light volcanic soils in coastal Bay of Plenty, Watson *et al.* (1998) showed that caucasian clover survived summer drought better than white clover.

Where perennial grass competition presents the major stress on pasture legumes, caucasian clover has also been more productive than white clover. In a range of irrigated grass/clover mixtures in Canterbury, Moss *et al.* (1996) reported slower establishment by caucasian clover compared with white clover but after 2 years caucasian clover pastures contained more legume than the five white clover/grass mixtures. Also in Canterbury, Black *et al.* (2000) have shown that caucasian clover/ryegrass pastures can produce more legume than white clover/ryegrass where soil moisture stress was eliminated by irrigation.

The field experiment reported in this paper was established to compare the competitive abilities of caucasian clover or white clover against the same five perennial grass species used by Moss *et al.* (1996). But in our experiment, the effect of moisture stress was investigated. Irrigation, to assist clover establishment, was applied in the first two summers after a late December 1994 sowing. No irrigation was applied subsequently. This 14-month establishment period was followed by 3 years with less than average rainfall and then a sixth year (1999/2000) with average rainfall. The objective was therefore to compare the competitive abilities of caucasian clover or white clover against five perennial grass species in a fertile lowland Canterbury environment without irrigation.

Materials and methods

The experiment at Lincoln University was sown on 20 December 1994 with three replicates of a split-plot design. 'Endura' caucasian clover (6 kg/ha) or 'Grasslands Demand' white clover (3 kg/ha) were sown as main plots with five perennial grass species ('Yatsyn' perennial ryegrass (*Lolium perenne*) infected with wild type endophyte (*Neotyphodium lolii*) (16 kg/ha), 'Grasslands Wana' cocksfoot (*Dactylis glomerata*) (6 kg/ha), 'Grasslands Advance' tall fescue (*Schedonorus phoenix* syn *Festuca arundinacea*) (20 kg/ha), 'Grasslands Gala' grazing brome (*Bromus stamineus*) (30 kg/ha), and 'Grasslands Maru' phalaris (*Phalaris aquatica*) (10 kg/ha)) as sub plots. The caucasian clover seed was inoculated with the specific *Rhizobium* strain ICC105 (Pryor *et al.* 1998). Grass sub-plots were 9 x 2.1 m.

The deep Wakanui silt loam was fallowed in spring/early summer before sowing and had a soil water holding capacity of 200 mm to a depth of 600 mm (K.M. Pollock pers. comm.). Plots were irrigated (about 100 mm) during establishment in the summers of 1994/1995 and 1995/1996, but received no further irrigation after the first 14 months. No fertiliser has been applied since sowing but a soil test in March 1996 indicated high soil fertility (pH 6.1, Olsen P 39). Sheep rotationally grazed the experiment about six times each year and plots were mown to a residual height of 40 mm after each grazing.

Measurements

Legume cover in March 1996 was determined by point analysis (Webb 1996). Dry matter production was determined before grazing after 7 weeks regrowth in February 1998 (Garb 1998) and March 1999, and after five 7- to 10-week-regrowth periods from July 1999 to June 2000. At each harvest, herbage was cut to 40 mm above ground level within two x 0.2 m^2 quadrats per plot and sub-samples were dissected to determine botanical composition before drying.

Statistical analysis

Significant (P<0.05) treatment differences were determined using two-way analysis of variance according to the split-plot design and standard errors of means are presented. Legume content data were arc-sine transformed when necessary.

Results

Rainfall

Rainfall in 1994/1995 averaged 90 mm per season (57% of the 158 mm long-term mean) over the three seasons spring (September–November), summer (December–February) and autumn (March–May) (Table 1). Spring–summer–autumn 3-month seasonal rainfalls averaged 137 mm (87%) in 1996/1997, 84 mm (53%) in 1997/1998, 104 mm (66%) in 1998/1999 and 163 mm (103%) in 1999/2000. In general, potential evapotranspiration exceeded rainfall for 8 months of the year (September–April) over the 6 years.

Table 1 Rainfall (mm) at Lincoln during winter (June–August), spring (September–November), summer (December–February), and autumn (March–May), from 1994/1995–1999/2000 and long-term average (1975–1991) rainfall and evapotranspiration (mm).

	Winter	Spring	Summer	Autumn	Annual Total
1994/1995	177	98	82	89	446
1995/1996	225	153	64	159	601
1996/1997	215	86	171	155	627
1997/1998	157	81	73	97	408
1998/1999	134	97	99	116	446
1999/2000	262	138	140	212	752
	Long-term means (1975–1991)				
Rainfall	205	151	163	161	680
Evapotranspiration	121	297	413	203	1034

Establishment

Initial establishment of four grass species was excellent but cocksfoot and clover species had low seedling populations. Clover populations were lowest in ryegrass and grazing brome treatments. Caucasian clover had populations of only four seedlings/m^2 when sown with grazing brome. Subsequently, clovers spread by rhizomes or stolons and resulted in legume presence throughout most plots after 2 years. Some volunteer white clover established in all 10 treatments.

Dry matter production

In February 1998, the amount of DM produced after 7 weeks regrowth was greater (P<0.05) from pastures sown with caucasian (1.2 t DM/ha) than white clover (0.8 t DM/ha) 3 years after sowing (Table 2). At this stage, DM production differed (P<0.05) across grass treatments independent of clover species. Cocksfoot produced the most (1.2 t DM/ha) compared with grazing brome, which produced the least (0.8 t DM/ha). In March 1999 (4 years after sowing), DM production after 7 weeks was similar between clover species (2.2 t DM/ha), but differed (P<0.05) across grass treatments. Cocksfoot pastures again produced more (P<0.05) herbage (2.4 t DM/ha) than the other four grasses (2.1 t DM/ha) independent of clover species.

During the sixth year (1999/2000), total DM production from July 1999 to June 2000 averaged 10.0 t DM/ha from caucasian clover pastures and 8.7 t DM/ha from pastures sown with white clover (Table 2), but was only significantly different between clover species in February 2000 (2.6 vs. 1.8 t DM/ha). Pastures

Table 2 Dry matter production (t DM/ha) from pastures sown in December 1994 with caucasian or white clovers and five perennial grass species after 7 weeks regrowth in February 1998 and March 1999, and from five 7- to 10-week harvests from July 1999 to June 2000.

Date	Clover	Companion Grass					SEM
		Cocksfoot	Ryegrass	Grazing brome	Phalaris	Tall fescue	
Feb 1998	Caucasian	1.5	1.1	0.8	1.2	1.4	0.15
	White	0.9	0.7	0.8	0.9	0.7	
Mar 1999	Caucasian	2.5	2.2	2.2	1.9	2.2	0.09
	White	2.3	2.1	2.1	2.1	2.1	
Jul 1999	Caucasian	10.6	9.5	10.4	10.6	9.0	0.57
–Jun 2000	White	10.3	8.4	8.7	9.1	7.3	

produced the most (P<0.05) total DM when sown with cocksfoot (10.4 t DM/ha) and the least with tall fescue (8.2 t DM/ha) regardless of clover species.

Legume content

The percentage of legume cover in pastures at 15 months of age in March 1996 was higher (P<0.05) when sown with white clover (29%) than caucasian clover (21%) (Table 3). The percentage of white clover then declined in all pastures over the following 23 months so that in February 1998, legume contributed 37% of the DM in caucasian clover pastures, but only 4% in pastures sown with white clover (P<0.05). Caucasian clover pastures at 4 years of age in March 1999 continued to produce more (P<0.05) legume (21%) than pasture sown with white clover (1%).

When sown with caucasian clover, 15-month-old cocksfoot and phalaris pastures averaged 27% legume cover, compared with 17% (P<0.05) for ryegrass, grazing brome and tall fescue (Table 3). In February 1998, legume contributed 41% of the DM in grass treatments other than grazing brome with 22% legume (P<0.05). Similarly in March 1999, phalaris and ryegrass pastures contained the most legume (27%) and tall fescue and grazing brome the least (15%) 4 years after sowing (P<0.05).

In white clover pastures, legume cover exceeded 40% with phalaris compared with 26% (P<0.05) for the other four grass species in March 1996 (Table 3). But in February 1998 and March 1999, the contribution of legume to production was uniformly low with all five grass species. For instance in March 1999, white clover was absent from pasture sown with cocksfoot, compared with 23% legume when cocksfoot was sown with caucasian clover (P<0.05).

During the sixth year (1999/2000), pastures continued to produce more (P<0.05) legume when sown with caucasian clover (20%) than white clover (7%) (Figure 1). The legume content of caucasian clover pastures was similar across all grass treatments, but in February reached 46% with cocksfoot compared with only 2% when cocksfoot was sown with white clover (P<0.05). However in February, phalaris (18%), ryegrass (16%) and tall fescue (15%) pastures each contained more (P<0.05) white clover than pastures sown with cocksfoot.

Volunteer white clover contributed 23% of the total legume produced in caucasian clover pastures during spring 1999 and autumn 2000, but only 10% of the total legume produced in December 1999 and February 2000.

Discussion

In irrigated pastures in Canterbury, caucasian clover demonstrated superior productivity over white clover when sown with a range of perennial grasses (Moss *et al.* 1996). The present experiment indicates caucasian

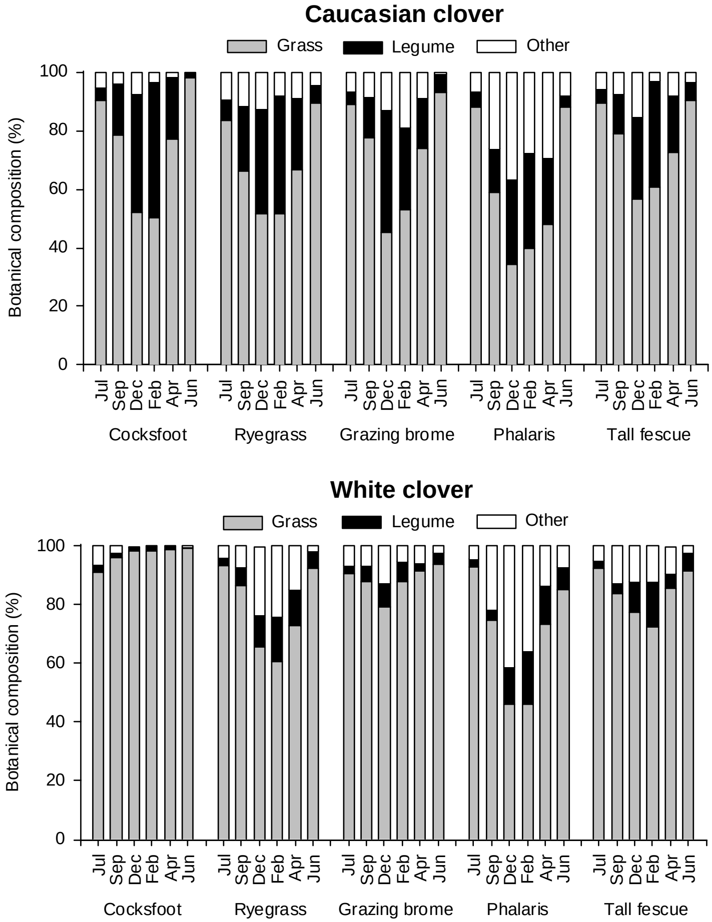
Table 3 Legume content of pastures sown in December 1994 with caucasian or white clovers and five perennial grass species as percentage of total legume cover in March 1996, and percentage total legume of dry matter produced in February 1998 and March 1999.

Date	Clover	Companion Grass					SEM
		Cocksfoot	Ryegrass	Grazing brome	Phalaris	Tall fescue	
Mar 1996	Caucasian	28	18	16	26	18	4.0
	White	27	24	27	41	25	
Feb 1998	Caucasian	42	43	22	34	43	3.0
	White	1	4	4	4	5	
Mar 1999	Caucasian	23	25	15	28	15	3.0
	White	0	1	1	3	1	

clover can also make a major contribution to the legume content of unirrigated pastures sown with the same perennial grass species used by Moss *et al.* (1996). The large difference in legume content observed between the two clover pastures in this experiment appeared to be largely owing to the weakness of white clover during summer drought.

The percentage of legume in pastures sown with white clover decreased dramatically when rainfall averaged only 53% of the mean during spring–summer–autumn of 1997/1998. In contrast, the legume content of caucasian clover pastures increased over time after poor initial clover establishment. This resulted in greater DM production from caucasian than white clover pastures at 3 years of age, and contributed to the extra 1.3 t DM/ha total DM from caucasian clover pastures in the sixth year (1999/2000). This more favourable season, when annual rainfall was 111% of the mean, enabled white clover pastures to reach 18% legume in February 2000. In contrast, the percentage of legume in pastures sown with caucasian clover reached 46%.

Figure 1 Botanical composition of pastures sown in December 1994 with caucasian or white clovers and five perennial grass species from July 1999 to June 2000.



Periodic moisture stress is a major constraint to the production of high quality forage in conventional white clover-based pastures in many parts of New Zealand, particularly in dry hill country and along the east coast (Williams *et al.* 1990). Hot dry summers, leading to soil surface temperatures lethal to white clover stolons and crowns (Watson *et al.* 1995), can severely reduce and delay the recovery of white clover as demonstrated in the present experiment. Much effort has been made to improve the tolerance of white clover to moisture stress through recurrent selection for greater tap-root diameter (Woodfield & Caradus 1987; Woodfield *et al.* 1995) and water use efficiency (Barbour *et al.* 1995). However, an extensive root system (Speer & Allinson 1985; Strachan *et al.* 1994) and protected underground growing points, has made caucasian clover an attractive alternative to white clover in drought prone coastal Bay of Plenty (Watson *et al.* 1997) and lower slopes of the South Island high country (Chapman *et al.* 1989; Woodman *et al.* 1992).

The volunteer white clover (probably 'Huia' establishing from buried hard seed) in the caucasian clover-based pastures contributed about 20% in spring and autumn but only 10% in summer to their superior total legume production. This mixture of clovers represents what is most likely to happen even where caucasian clover is sown without white clover because of the widespread presence of white clover seed in New Zealand pastoral lands. Elliot *et al.* (1998) discussed the possibility of poor sociability between caucasian and white clover because of rhizobial incompatibility. However, in this and other experimental sowings (e.g., Black *et al.* 2000; Moss *et al.* 1996; Watson *et al.* 1996), caucasian clover has appeared to be complementary rather than competitive towards white clover.

Caucasian clover-based pastures produced a greater proportion of legume than white clover across all grass species. However, the most important specific result was the dramatic difference in legume content between clover treatments in pastures sown with cocksfoot. Cocksfoot has a reputation as a very aggressive grass species in fertile lowland environments, where the suppression of high quality companion grasses and clovers has resulted in poor grass productivity and palatability (Moloney 1995). After more than 5 years of association, the total legume content of cocksfoot/caucasian clover pastures in February 2000 (46%) was superior to that based on white clover (2%). If caucasian clover can be established it is likely to improve the nutritive value of pastures in many dryland environments where cocksfoot is the most persistent grass species.

Grass grub damage in ryegrass pastures during 1998/1999 and 1999/2000 limited production but created space for annual grass weed species to establish. Consequently in February 2000, the percentage of white clover in ryegrass (16%) pasture was similar to that in tall fescue (15%) and phalaris (18%) pastures, which generally have an erect open canopy structure favourable for white clover growth. In contrast, grazing brome was less sociable with white clover, which may have been owing to its relative unsuitability to the rotational grazing applied in this study (A. Stewart pers. comm.).

The total dry matter yield of 10 t DM/ha reached from pastures in 1999/2000 compared unfavourably with 19 t DM/ha from 3-year-old dryland lucerne during the same year on the same soil type in an adjacent area at Lincoln University (D.J. Moot pers. comm.). In the very dry 1998/1999 season, the 2-year-old lucerne without irrigation produced 21 t DM/ha but the annual pasture production from our experiment would have been much less than the 10 t DM/ha achieved during a slightly wetter than average 1999/2000 year. These yields from the deep and fertile Wakanui silt loam would suggest that lucerne should be grown wherever possible in the summer dry Canterbury plains environment. Unfortunately, it is very difficult to manage a pastoral farm with more than 50% of the area planted in lucerne. The balance of these properties will normally be in grass/clover pastures with a limited area of winter forage. It is therefore very important that efforts are continued in the search for persistent high quality pasture species for dryland areas.

Conclusions

The present experiment indicates caucasian clover can make a significant contribution to the productivity and nutritive value of dryland grass/clover pastures in sub-humid environments. Specific conclusions were:

1. Once established, caucasian clover will enhance the proportion of total legume produced in lowland pastures.
2. Caucasian clover is more tolerant of dry soil conditions than white clover.
3. Caucasian clover is much more compatible with 'Wana' cocksfoot than white clover.
4. Conventional grass/clover pastures are relatively low yielding compared with lucerne in the sub-humid areas of New Zealand.

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