Autumn Performance Of Rhizomatous Clovers After a Summer Drought, Under Different Grazing Treatments

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By

Wayne W. Nichol

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Certificate

I hereby certify that the work embodied in this dissertation was carried out by the candidate under my supervision.

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Abstract of a dissertation in partial fulfilment of the requirements for the Degree of Bachelor of Agricultural Science (Honours).

Autumn Performance Of Rhizomatous Clovers After A Dry Summer, Under Different Grazing Treatments

By Wayne W. Nichol

Caucasian clover (*Trifolium ambiguum*; cv. Monaro and Alpine), zigzag clover (*Trifolium medium*; seed lines, Kentucky and Porters Pass) and white clover (*Trifolium repens*), were evaluated in a sheep grazing trial on a lowland medium fertility soil (Templeton silt loam) at Lincoln University, Canterbury.

Each rhizomatous clover cultivar / seed line was sown (March, 1989) in plots with four rows 0.75m apart, 80m long. There were three replicates of these plots (1.5m apart), each replicate arranged as randomised blocks. The site was oversown with Marsden high endophyte ryegrass (*Lolium perenne*) in the spring of 1992. Volunteer white clover Huia was present throughout the trial site.

The 80*3m plots were split into eight grazing plots 10*56m rows in August 1993 by fencing, at right angles across the original plots. This resulted in 12 clover subplots in each main grazing plot. The eight main plots were divided into two replicates of four grazing treatments: two levels of grazing intensity (Lax (L) and Hard (H)) and two levels of grazing frequency (Set stocked (S) and Rotational grazing (R)). The four grazing treatments were first applied in

September 1993, and then continued in early-February 1995 after having not been grazed since late December 1994. Set stocked lax pastures were grazed for 2.5 days after an interval between grazing of 4.5 days to maintain a pasture mass of about 1700kg DM/ha. Hard set stocked pastures were maintained at between 600 to 800kg DM/ha by grazing every 4.5 days with a 2.5 day interval between grazing. Hard rotational grazed treatments aimed to have a pre-graze herbage mass of between 1500 to 2000kg DM/ha 25 days after grazing and a post herbage mass of 600 to 800kg DM/ha after 5 days grazing. Lax rotational grazed paddocks were spelled for 25 days to achieve a pre-grazed herbage mass of 2000 to 3000kg DM/ha then grazed for 3 to 4 days to a post-herbage mass of 1500 to 2000kg DM/ha.

Botanical analysis, clover morphology and grass characteristics were measured in all grazing treatments prior to grazing of the rotational grazed pastures in April, May, June and in early October after plots were grazed approximately every six weeks to a herbage mass of about 800 kg DM/ha.

The intensity of the hard set stocking treatment was indicated by reduced ryegrass tiller populations, tiller weight and length by 50% compared to the lax set stocked treatment. Infrequent grazing favoured ryegrass growth and tillering.

The hexaploid Monaro Caucasian was the superior clover in the lax rotational grazed treatment covering 14.3 to 29.3% of the subplots. Swards dominated by Monaro reduced other sward components. Hard set stocking of pasture reduced the percentage cover of all rhizomatous clover species; only white clover (8.4 to 18% cover) and weeds (16 to 24% cover) increased under the extreme grazing pressure. Hexaploid Monaro Caucasian cover was superior to the diploid Caucasian cv. Alpine in cover and all growth characteristics. Hard rotational grazing treatments increased the number of clover growing points more than the other treatments for Caucasian and white clover species. Clovers in lax grazing treatments had longer petioles, but petiole growth potential may have been reduced by declining soil and air temperatures. Zigzgag clover generally had a very low cover and growing point populations, but lax infrequent grazing favoured zigzag most.

An assessment of underground biomass in early August 1995, showed that the root weight of Monaro Caucasian (202g DM/m^3) far exceeded that of white clover (9g DM/m^3). Rotationally grazed treatments had significantly ($P<0.007$) more Monaro underground biomass (330g DM) than set stocked treatments (78gDM/m^3). This may reflect the preferential grazing of clover in reference to the high endophyte ryegrass.

A supplementary study conducted on old seed plots beside the main trial site, was grazed to a herbage mass of 450kg DM/ha on the 5th of May and used to evaluate the regrowth of clover over 50 days. Monaro Caucasian clover and white clover produced far more growing points than any other of the clovers measured (5280 and 4790 growing points/m^2 respectively). Petiole length of all clovers increased during the 50 day period, particularly Monaro Caucasian and stoloniferous white clover (up to 73mm). Growth of all but white clover slowed from 24 to 50 days indicating that the other rhizomatous species were becoming dormant due to low temperatures (Mean air temperature in May 9.7^{o}C and June 6.2^{o}C).

Results from the experiment confirm the choice of hexaploid Caucasian clover for commercial pastoral development. Zigzag clovers were very low producing and uncompetitive with ryegrass under the range of treatments used. Alpine Caucasian (2n) was less productive than Monaro (6n).

The reduced underground biomass of set stocked Monaro suggests that the rhizomatous habit may not be the ultimate response to continuos hard grazing and that some autumn spelling and or rotational grazing may be necessary to maintain root and rhizome reserves.

Keywords: White clover (*Trifolium repens*), Caucasian clover (*Trifolium ambiguum*: cv. Alpine, cv. Monaro), zigzag clover (*Trifolium medium*: seed lines; Kentucky, Porters Pass), perennial ryegrass (*Lolium perenne*), rotational grazing, set stocking, grazing intensity temperature response and *Lolium* endophyte.

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Chapter 1

Introduction

The most important environmental factors influencing farming and the choice of pasture species in the hill and high country of the South Island are temperature, soil moisture, soil fertility and pasture management (Scott, Keoghan, Cossens, Maunsell, Floate, Wills and Douglas, 1985).

In New Zealand there has been an urgent need to identify legumes that are able to persist in low fertility and low rainfall pastoral systems (Daly and Mason, 1987). Pastoral development in hill and high country relies on successful establishment growth and nitrogen inputs of legumes. This requires correction of deficiencies of phosphorus, sulphur and sometimes lime. For the high country, legume species need to be tolerant of low fertility soils, grass grub attacks, low temperatures and be able to compete with aggressive grasses such as brown top (*Agrostis capillaris*). Experimental work in the South Island hill and high country has indicated that the rhizomatous clovers Caucasian (*Trifolium ambiguum*) and zigzag (*Trifolium medium*) have potential as legumes for these environments (Scott *et al*, 1985).

Caucasian clover (*Trifolium ambiguum*; Plate1.1) is a perennial legume that produces an extensive network of rhizomes that enables it to persist under climatic extremes and under frequent close defoliation. The species also forms a deep, branching tap root, conferring drought resistance (Peterson, Sheaffer, Jordan and Christians, 1994a; Sheaffer, Marten, Jordan and Ristau, 1992).

Zig-zag clover (*Trifolium medium*; Plate 1.2), is also rhizomatous and persistent. Its main value is its persistence and ability to survive and spread in a rigorous climate with low rainfall (Daly and Mason, 1987).

The rhizomatous nature of these two species gives them considerable advantages over stoloniferous white clover (*Trifolium repens*; Plate 1.3), the most commonly sown legume in New Zealand, in terms of their persistence under different grazing regimes (Daly and Mason, 1987).

Although rhizomatous clovers have shown potential in the hill and high country of New Zealand, a review of the literature suggests that little or no research has been conducted on the tolerance and competitive ability of Caucasian and zigzag clovers with commonly sown species such as high endophyte ryegrass (*Lolium perenne*) and cocksfoot (*Datcylis glomerata*), in low-land, high fertility environments under different grazing management practices.

An going grazing experiment was used to study responses of three clover species (white clover, Caucasian clover and zigzag clover all sown with high endophyte Marsden ryegrass) to four grazing treatments;

SH = Set stocked hard

SL = Set stocked lax

RH= Rotationally grazed hard

RL = Rotationally grazed lax.

Preliminary observations indicated that Monaro Caucasian was the best of the rhizomatous species. Detailed morphological measurements were made on all three species under the different grazing treatments.

A supplementary study in late autumn evaluated the response of the sown clover species to grazing compared to white clover.

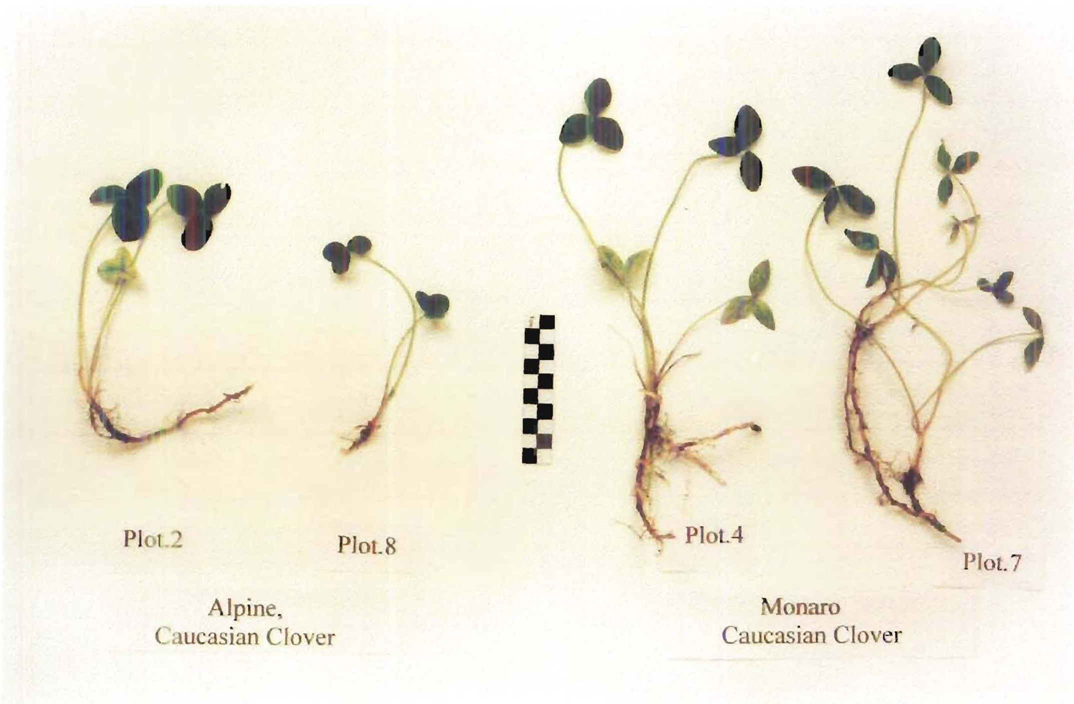
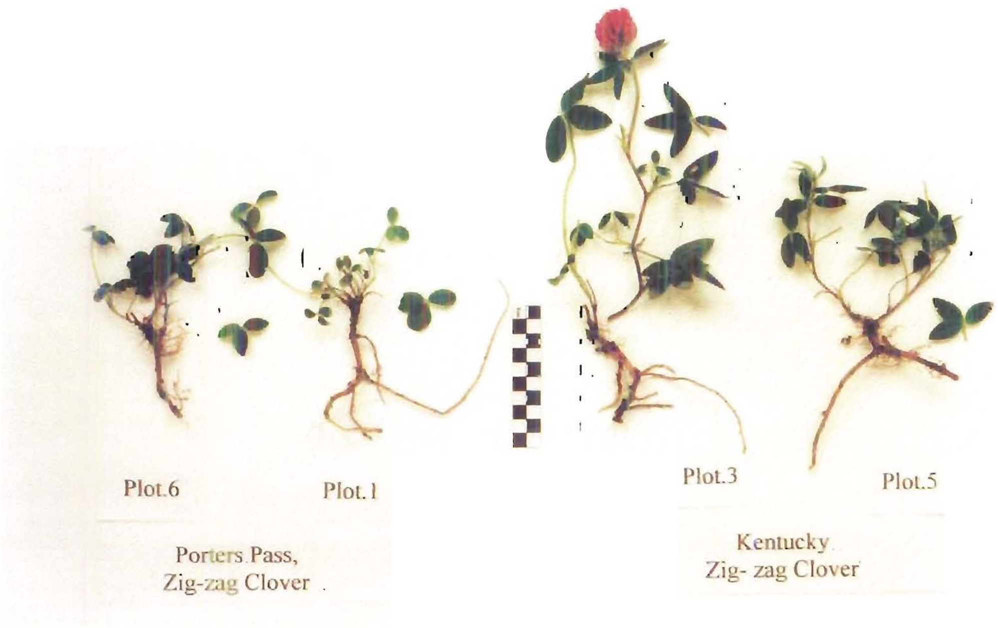
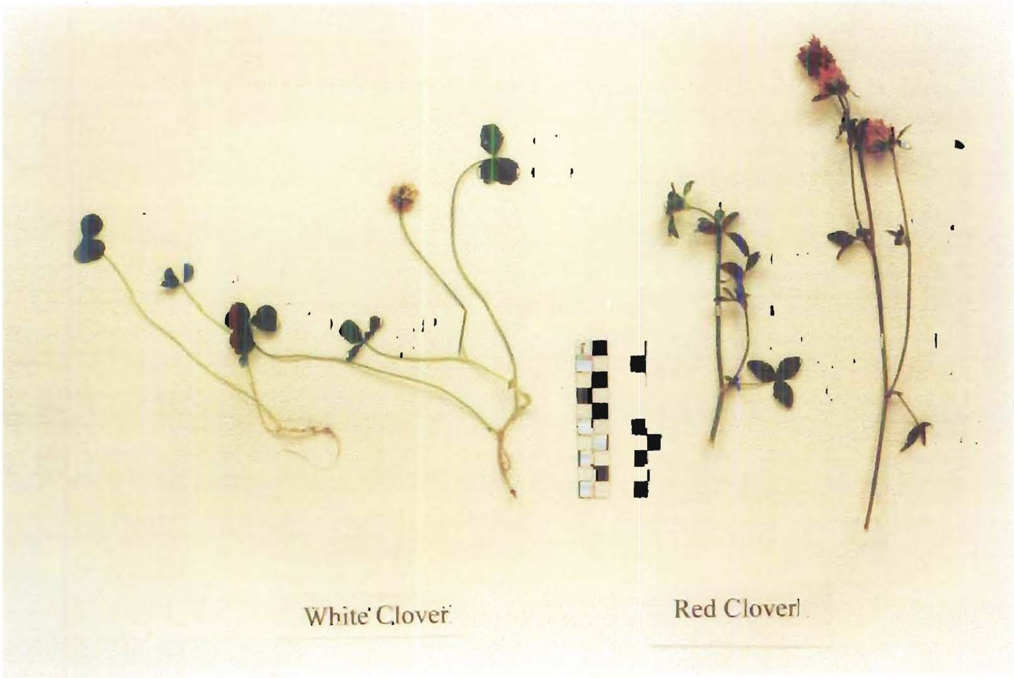


Plate 1.1 Caucasian clover (*Trifolium ambiguum*); cv. Monaro and cv. Alpine taken from supplementary study trial plot area in early April.



1.2 Zigzag clover (*Trifolium medium*); seed lines Kentucky and Porters Pass taken from supplementary study area in early April.



1.3 Volunteer white clover (*Trifolium repens*) and red clover (*Trifolium pratense*) taken from the supplementary study plot area in early April.

Chapter Two

Literature Review

2.1.1 Rhizomatous clovers

The literature which refers to two species of rhizomatous clovers, zigzag clover and Caucasian clover, is reviewed in this chapter with particular emphasis on the cultivars used in this study.

Caucasian clover (*Trifolium ambiguum* M.Bieb) is a long lived perennial species which has the ability to adapt to a wide range of environments (Bryant, 1974; Dear and Virgona, 1995). A native of Caucasian Russia, eastern Turkey and northern Iran (Khoroshailov and Federenko, 1973), Caucasian clover is also called Kura, Pellet, Honey or Deer clover in the USA (Pellet, 1945).

Caucasian clover is a low crowned, morphologically diverse species which has three ploidy levels: diploid, tetraploid and hexaploid (Oram, 1990). The species was primarily investigated in New Zealand and Australia for mountain re-vegetation purposes. Long term, the plant persists well under continuous grazing and low phosphate conditions compared to white clover and subterranean clover (Dear and Virgona, 1995).

Zigzag clover (*Trifolium medium*), is also known as mammoth clover, meadow clover, and perennial or forest clover. It has been present in New Zealand for many years, but how it arrived in New Zealand is uncertain (Lobb, 1957). The species grows throughout Eurasia and is native to that area (Hansen, 1909), but is now naturalised in North America, in eastern Canada and New England (Townsend, 1985).

In appearance zigzag clover is very much like red clover, but unlike red clover it has extremely vigorous rhizomes which assists its survival and spread in extremely cold climates with low rainfall (Lobb, 1957).

2.1.2 Genetic characteristics

Caucasian clover is taxonomically related to white clover (Spencer, Govaars and Hely, 1980). There are diploid, tetraploid and hexaploid forms within the Caucasian species, with a basic 2x number of 16, 32 and 48 respectively (Hely, 1957). Kannenberg and Elliott (1962) examined the morphological and physiological characteristics of the three chromosome races and found overlapping ranges for most of the measurable characteristics although the mean values were usually indistinct, which indicates an extremely heterozygous species.

In Australia six cultivars of Caucasian clover have been registered for use, Summit (2N), Forest (2N), Treeline (4N) and more recently Alpine (2N) and Monaro (6N) (Oram, 1990).

Zigzag clover is a poly-ploid with chromosome numbers ranging from 64 to 80 (Quessenberg and Taylor, 1977; Taylor, 1995). Robertson and Armstrong (1964) assumed that high and variable chromosome numbers were associated with irregularities at meiosis.

No named cultivars of zigzag clover have been released, however some germplasms have been released in the U.S.A. (Townsend, 1985); C1 (Townsend, 1971), C-20 (Faust and Gasser, 1980), Ky M1 (Taylor, Cornelius and Sigafus, 1982), KyM2 (Taylor, 1991) and CRS-Z-1 (Christie and Choo, 1991).

Rhizomatous species are highly self-incompatible, freely cross pollinating plants. Seed yields, therefore, have been found to be determined largely by the availability of bees for cross fertilisation (Kannenberg and Elliott, 1962).

2.1.3 Morphology

Caucasian clover exhibits a wide range of morphological variation, due in part to the presence of a range of ploidy forms. In general Caucasian clover is a pasture-type rather than a hay-type species (Townsend, 1970).

2.1.3.a Leaf morphology

Townsend (1970) reported considerable variability for plant vigour, height, spread, date of flowering , growth habit and plant colour when 51 progenies representing all three ploidy levels were observed. The most vigorous plants were hexaploid, however some diploids were nearly as vigorous (Townsend, 1970). The growth habit of the hexaploid (cv. Monaro) is more erect than diploids, with more daughter plants, a greater rhizome length and is more robust (Oram, 1990). The ploidy levels of Caucasian clover affect both the leaf shape and leaflet area (Kannenberg and Elliott, 1962). Leaflet shape as indicated by the ratio of leaflet length to width, varies according to ploidy (Dear and Zorin, 1985). Diploid (cv. Summit 365 mm^2, cv. Alpine 436 mm^2, cv. Forest 467 mm^2) and tetraploid (cv. Treeline 448mm^2) have similar leaf areas while hexaploids (cv. Prairie 609mm^2, cv. Monaro 644mm^2) have substantially larger leaves. Leaf markings vary between ploidy and within ploidy levels (Oram, 1990).

2.1.3.b Root morphology

Caucasian clover produces an extensive network of rhizomes, which enables it to persist under a wide range of climatic extremes and under frequent and close defoliation (Dear and

Zorin, 1985; Peterson, Sheaffer, Jordan and Christians 1994b; Speer and Allinson, 1985; Sheaffer *et al*, 1992; Stewart and Daly, 1980; Woodman, Keoghan and Allan, 1994). Rhizomes produce daughter plants both terminally and from nodes, and gradually form a massive root and rhizome system which enables it to survive under low fertility conditions (Stewart and Daly, 1980). Dear and Zorin (1985) in the New South Wales highlands, showed that two of the more vigorous cultivars Monaro and Alpine, produced dense interlocking swards four years after sowing. Rhizome length was positively correlated with the number of daughter plants produced and not influenced by ploidy. Parent plants of Caucasian clover produced a strong tap root system comprising 4 to 6 thick main roots 30 to 40cm deep (Dear and Zorin ,1985).

Stewart and Daly (1980) reported that the dry matter yield of roots and rhizomes of cv. Treeline from a $0.5m^2$ sample was $1164g/m^2$ in the top $17cm^2$, and 12600kg/ha for the total underground biomass growing in a fertile Wakanui silt loam at Rangiora, Canterbury.

Strachan, Nordmeyer and White (1994) studied 13 year old roots and rhizomes of hexaploid Caucasian clover in a South Island New Zealand montane area (altitude 600m and rainfall 800mm) and showed that extensive networks of roots and rhizomes combined to give root:shoot ratios of up to 4.6:1 with root plus rhizome biomass up to 20 t/ha.

Compared with white clovers, roots of Caucasian clovers grow to a greater depth and are more stouter (Spencer, Hely, Govaars, Zorin and Hamilton, 1975).

Zigzag clover is highly persistent perennial, which spreads by strong, creeping rhizomes and resembles red clover in floral and forage characteristics (Townsend, 1967). The name zigzag clover was derived from the nature of the stems which alter direction slightly at each node. Zigzag clover has narrow-elliptic hairy leaflets and red-purple florets and when grown under favourable conditions will produce yields similar to that of red clover (Healy, 1982; Townsend, 1967). The growth habit of zigzag clover is variable, ranging from low growing 'pasture' types to upright 'hay' types (Healy, 1982). Townsend, Dotzendo, Storer and Edilin (1968) found that the up-right growing genotypes produced significantly more forage than the intermediate and low growing types.

2.1.4 Seasonal production

Described as an alpine or mountain plant, Caucasian clover grows rapidly in spring, is hardy under drought conditions and is winter dormant (Khorohailov and Fedorenko, 1973). Dear and Zorin (1985) reported similar growth patterns with only a few short green leaves appearing above ground in mid-September with a peak in vegetative production in late November.

Caucasian clover flowers profusely and is one of the first forage legumes to flower in the spring (Townsend, 1970). Diploid forms tend to flower earliest, but the date of flowering over-laps at all ploidy levels (Kannenberg and Elliott, 1962; Townsend, 1970). Flowering of hexaploid cv. Monaro commences some two weeks later than the diploid cultivars Summit and Forest (Townsend, 1970).

Maximum growth of zigzag clover takes place from late summer to early autumn with some growth in mid to late spring. Like Caucasian clover, zigzag clover over-winters in a dormant state from late autumn onwards (Lobb, 1957).

2.1.5 Persistence of rhizomatous clovers

2.1.5.a Winter dormancy

Bryant (1974), reported that the Caucasian species has been collected from areas as high as 3170m in eastern Turkey, which suggests that it can tolerate long and severe winters. At three observation sites (altitudes; 800m, 1280m, 1585m) in the Australian Snowy Mountains, it was found that Caucasian clover had variations in frost tolerance between genotypes and between ploidy levels. Hexaploid lines are most affected by frost during the growing season, suggesting that the diploid lines are more likely to be found at higher altitudes than hexaploid lines (Bryant, 1974).

High root plus rhizome to shoot ratios at low temperatures have been suggested as a mechanism of response to cold environmental temperatures (Daly and Mason, 1987). Dear and Zorin (1985) observed that root:shoot ratio in Caucasian clover was 6:1 and also noted that root to shoot ratio increased with low fertility and harsher climates. The ratios for fertile lowland (30m), dry hill country (650m) and infertile high hill country (1000m) were 1.0, 2.3 and 2.7 respectively.

Vegetative growth in Caucasian clover tends to decrease at low temperatures (15°day/5°C night) compared with higher temperatures (20°/10°C) (Mears, 1975). Higher yields are therefore obtained at higher temperatures (25°C day/20°C night) than at lower temperatures (10°C day/ 3°C night) (Paljor, 1973). Root to shoot ratio and tap root length increased at low temperatures (Mears, 1975; Paljor, 1973; Stewart, 1979). The development of high root to shoot ratios at low temperatures is a response to cold environmental stress (Daly and Mason, 1987).

2.1.5.b Drought

Caucasian clover survives summer drought, by becoming dormant during drought stress conditions (Dear and Zorin, 1985). Past research has shown that when Caucasian clover and white clover are grown at medium elevations. *Trifolium ambiguum* has substantially more lateral spread under prolonged periods of drought compared to white clover, which usually dies as a result of the prolonged drought (Spenser *et al.*, 1975). Drought tolerance appears to occur more in the 2N forms, but drought hardy 4N and 6N cultivars have been developed (Bryant, 1974). Drought resistance in both Caucasian and zigzag species is achieved with their deep, branching taproots (Peterson *et al.*, 1994b).

Zigzag clover has a very strong root system and has shown the ability to persist on infertile soil in the Mackenzie country, where stands survived for 20 years without fertiliser (Daly and Mason, 1987). Zigzag clover has the ability to survive and spread after hawkweed invasion. Rhizomes are well branched with lateral roots therefore increasing the volume it occupies within the soil allowing it to better exploit the soil for nutrients and soil moisture (Mason, 1987).

2.1.6 Herbage production

Initial herbage production after sowing has been low in Caucasian clover cultivars, due to the species having relatively greater development of large roots and rhizome systems (Dear and Zorin, 1985; Spenser *et al.*, 1975; Stewart, 1979). Early studies suggested that Caucasian clover had low growth and assimilation rates (Paljor, 1973), partially effective nodulation (Zorin, Brockwell and Muller, 1976) and a low rate of phosphate uptake (Mears, 1973).

After 17 months of growth white clover accumulated 3.6 times more herbage dry matter than Caucasian clover (Spenser *et al.*, 1975). Dear and Zorin (1985) described Caucasian clover as having the potential to be highly productive when conditions are favourable or when the clover is not in a reproductive state. Once established Caucasian clover is capable of producing yields that are comparable to those produced by other legumes (Dear and Zorin, 1985).

Daly and Mason (1987) compared the performance of Prairie Caucasian clover and Huia white clover on a stoney drought prone Haldon silt loam (altitude 650m and rainfall 600mm) at Hunua, North Canterbury, 12 years after establishment and found Prairie Caucasian clover was twice as productive as white clover. Prairie dry matter production was maintained at 4.7t/ha in the fourth year while that of Huia white clover declined from 2.5 to 1.3t/ha from the third to the fourth year. Daly and Mason (1987) also reported herbage production at a number of other fertility regimes. Highest productivity (12t/ha) was recorded on a lowland Wakanui soil (Olsen P 19-25) followed by the moderately productive (8.5t/ha) dry hill country Haldon soil (Olsen P 16). The lowest herbage production (2.5t/ha) was recorded in the infertile high country Cass soil (Olsen P 8).

An earlier trial by Lucas, White, Daly, Jarvis and Meijer. (1980) compared the establishment and productivity of 'Grassland Maku' lotus (*Lotus pedunculatus*), white clover and Prairie Caucasian clover (6N) on an acidic, infertile tussock grassland montane site at Mesopotamia Station, inland South Canterbury, New Zealand. Initial productivity of Caucasian clover was low compared to the other legumes partially because of low seedling populations, however four years after sowing, productivity between the species was not significantly different. The spring yields in year four were 2.5t, 2.3t and 2t for *Lotus*, white clover and Caucasian clover respectively. Twelve years after the trial was established the Caucasian clover was out yielding the other two legumes (Daly and Mason, 1987).

In a further trial at Mesopotamia Station the effects of establishment techniques and fertiliser applications on seedling establishment and early root and rhizome development of Caucasian clover were reported by Moorhead, White, Jarvis, Lucas and Sedcole (1994). Seven months after the trail was established on a depleted tussock grassland site, tap root length of the Caucasian clover was >150mm compared with white clover which was shorter in length (92mm). Tap root diameter of the Caucasian clover (4.8 mm) was markedly larger than that of the white clover (3.4 mm). Leaf weight of both Caucasian clover (0.21 g/plant) and white clover (0.20 g/plant) were similar, however Caucasian root material per plant (0.81 g/plant) was more than three times heavier than that of white clover (0.26 g/plant).

Townsend *et al* (1968) found marked differences in yields among genotypes for zigzag clover. Average forage yields in 1965 from established stands ranged from 1960kg DM/ha for genotype 4 to 7200 kg DM/ha for genotype 6. Quality of zigzag hay appears to be similar to that of other stemmy clover species such as red clover (Townsend *et al*, 1968).

2.1.7 Grazing management

Peterson *et al* (1994b) stated that Caucasian clover persisted under a wide range of grazing regimes because the rhizomes and growing points are below ground level. Caucasian clover has large underground carbohydrate reserves, which means they do not have to re-establish from seed after the pasture has been heavily grazed in autumn (Peterson *et al*, 1994b).

No defoliation studies are available on *T. medium* but some recent work from USA (Peterson *et al* 1994 a and b and Sheaffer *et al* 1992) and Allan and Keoghan (1994) in New Zealand has indicated the excellent adaptation of *T. ambiguum* to a variety of grazing treatments.

2.1.7.a Forage studies

Sheaffer and Marten (1991) reported forage yields of Caucasian clover over three cutting treatments at Rosemount, Canada. Yields were 7.2, 9.2, 9.2 kg/ha for the 2 cut, 3 cut and 4 cut treatments per season, compared to lucerne which on average yielded 40% more than the clover production cuts. Percentage ground covers were 95%, 95% and 91% for the 2 cut (28 June, 27 August), 3 cut (3 June, 15 July, 27 August) and 4 cut (24 May, 28 June, 1 August, 5 September) schedule, compared to 53%, 54% and 38% for lucerne at the final harvesting in June.

At the Tara Hills hill country research station, in the South Island of New Zealand, Caucasian plants survival and spread was ranked the highest of the legumes investigated (Allan and Keoghan, 1994). The trial compared three stocking rates low or traditional (2 SU/ha), medium (3 SU/ha) and high (4 SU/ha), with three management practices at each stocking rate; continuous stocking, alternate grazing (2 paddocks with stock shifts every 2-3 weeks) and rotational grazing (6 paddocks with weekly stock shifts). Individual plant survival of Caucasian clover was 67.5%, 80% and 53% respectively compared with 'Huia' white clover with 54%, 42.5% and 3%. Both spread and vigour of Caucasian clover increased with stocking rate. Caucasian clover was the only material tested to show significant spread from the original planted row (averaged 582mm across all grazing treatments) (Allan and Keoghan, 1994). Results of this experiment reported by Allan and Keoghan (1994) and other grazing trials show that Caucasian clover is tolerant of a wide range of grazing managements, but it appears to show greatest spread and vigour under rotational grazing at higher stocking rates (Allan and Keoghan; 1994; Allan, O'Conner and White 1992; Peterson *et al*, 1994a).

Peterson *et al* (1994a) reported a decline in the forage production of Caucasian clover as defoliation frequency increased. Observations by Peterson *et al* (1994a) saw morphological responses in Caucasian clover with reduced petiole length and leaf blade size, especially under continuously stocked grazing treatments.

2.1.7.b Roots and rhizomes

Frequent defoliation was associated with depletion of Caucasian clover root carbohydrate reserves (Sheaffer *et al* 1992). Peterson *et al* (1994a) found that close grazing removes more growing points and leaves than lax grazing.

Peterson *et al* (1994b) found that the total below-ground mass (TBM) of a 5 year old stand of Caucasian clover in spring was 7140 kg/ha. Two years of clipping treatments and grazing with 28 day rest periods produced a cyclic pattern for TBM of increasing in the autumn and decreasing in the spring. After two years, in the spring of 1992 the TBM had declined to 5720 kg/ha under both clipping and grazing treatments. Primary crown and primary tap root mass and number were similar for all grazing treatments and followed a cyclic pattern similar to that outlined above. Secondary crown number and mass varied with grazing treatment.

2.2.1 White clover

White clover (*Trifolium repens* L.) is the most important pasture legume in the humid temperate zones of the world (Frame and Newbould, 1986). It is of value because of its wide climatic range, its high nutritional quality, digestibility of its herbage and the significant contribution it makes to maintaining the nitrogen content of the soil (Gibson and Cope, 1985). White clover aids pastures by fixation of atmospheric nitrogen, especially in the absence of fertiliser nitrogen and also it is very well adapted to close grazing due to its stoloniferous habit (Brock, Caradus and Hay, 1989; Frame and Newbould, 1986; Gibson and Cope, 1985).

White clover is a highly branched, creeping perennial (Turkington and Burdon, 1983), but in some environments and management situations it behaves like an annual, or even as a mixture of plants of both types. It is not tolerant of drought, excess water, or soils that are saline, highly alkaline, or acidic (Gibson and Cope, 1985).

This review of white clover literature covers refers mainly to the medium leaf size cultivar Huia which has been extensively used in New Zealand pastures since 1964 (Brock *et al*, 1989).

2.2.2 Genetic characteristics

White clover is virtually 100% outcrossing, although selfing can be induced with difficulty and with severe in-breeding depression. Natural populations are highly heterozygous and heterogenous. The species exhibits considerable phenotypic plasticity which has a strong genetic component (Williams, 1987a; Williams, 1987b). *Trifolium repens* is a tetraploid species (2n = 4x =32) with diploid sexual system and disomic inheritance (Gibson and Cope, 1985; Williams, 1987a).

There are basically three types of white clover which vary in size and growth habit. The largest and most upright of these is derived from the Mediterranean area, it is highly productive in low stress situations, usually refereed to as Ladino. At the other end of the scale is the wild type white clover, a highly persistent small leaved perennial which does not excel in productivity, normally found in older type pastures. The third group is characterised by cv. Huia which is a combination of the highly productive Ladino type clover with the grazing tolerant wild type clover (Gibson and Cope, 1985). The main morphological features used to distinguish white clover (*Trifolium repens* L.) cultivars are differences in size of plants and their individual parts (Harper, 1977).

2.2.3 Morphology

2.2.3.a Stolons

White clover plants develop an extensively branched tap root system from the primary seedling. Thereafter the adventitious roots with numerous lateral branches arise from the nodes of the stolons which develop from the mother plant. The clover tap root is short lived, so the plant is eventually dependent on the roots which develop from stolon nodes (Hollowell, 1966).

Hay (1983), showed that white clover stolons were present both above and below ground and more recently a seasonal pattern in distribution has been described (Brock, Hay, Thomas and Sedcole, 1988). Growth and survival of white clover is therefore dependent on stolon development and replacement. Stolon production is influenced by temperature, light and flower initiation (Frame and Newbould, 1986). Rotting of older basal portions of stolons, causes the severance of branch stolons which then form new plants (Chapman, 1983).

2.3.2b Trifoliate leaves

The rate at which leaves appear and the weight they attain depends on the season and more importantly on temperature and light (Brougham, 1962). Leaves are borne alternately, one per node (Gibson and Cope, 1985). Leaflet size and shape are functions of the clover variety, and the position of the leaflet on the stolon. Leaflet size is currently used for classifying the varietal type (Erith, 1924).

The process of leaf initiation, development, growth and senescence is affected by the prevailing temperatures and light (Brougham, 1962). In a cool moist environment, a leaf lives about 40 days from bud to senescence. New leaves are formed throughout the growing season (Gibson and Cope, 1985).

Flowering: Globular inflorescences are borne on large peduncles arising from the axis of leaves, and are produced from the nodes of the stolons, but not at the basal nodes (Erith, 1924). Flower production is usually greatest in early summer. Flowering extends over several weeks, and is influenced by many factors including genotype, temperature, photoperiod and management (Gibson and Cope, 1985).

2.2.4 Seasonal production

2.2.4.a Stolon production

Stolon production is temperature and light dependent (Munro and Hughes, 1966). Minimal growth occurs at temperatures below 5.0°C, in mid-June to mid-August in New Zealand. When soil temperatures go below 7.0°C there is little elongation of stolons (Chapman, 1983). Maximum rates of stem elongation occur in late spring (mean growth rate 32-35mm per week) as the temperatures approached 20-25°C (Harris, Rhodes and Mee, 1983). Stolon extension at lower temperatures is dependent on genotype (Ollerenshaw, 1983). Beinhart (1963) showed that branching from primary nodes of white clover was greatest at 10°C.

2.2.4.b Trifoliate leaf production

Rates of leaf appearance increase with increasing temperatures. In late autumn and winter the leaves in the older parts of the stolons generally die away, leaving mainly undeveloped leaves near the stolon apices (Davies and Evans, 1982) but there can be a steady but slow production of leaf throughout the winter. This is followed by a nett increase in dry weight when spring temperatures and radiation increase (Frame and Newbould, 1986). Haycock (1981) found that the rate of leaf appearance increased linearly within the temperature range of 5-11°C, with the apparent threshold being 2.6°C. Brougham (1958) showed that the petioles of developing leaves subject to low light intensity at the base of the sward continue to elongate until their laminae penetrate the existing canopy to reach full sun light. Maximum petiole lengths of 400 mm in undisturbed swards have been recorded in New Zealand (Brougham, 1962). Results from Arnott and Ryle (1982) indicate that doubling the day length from 8 to 16 hours or increasing day/night temperature from 15/10°C to 20/15°C increases the rate of leaf production by 15-20% as well as increasing the final leaf area.

2.2.5 Persistence of white clover

Flowering and growth of white clover are affected by radiation, day length, temperature, soil water and in exposed places wind. Severe frosts and prolonged drought will reduce both growth and/or survival of the clover (Frame and Newbould, 1986).

Variations in branching may be caused by lack of moisture or soil fertility particularly when under very intensive grazing (Curll and Wilkins, 1981). Close defoliation of ryegrass/white clover swards encourages stolon branching (Haggar, Holmes and Innes, 1963).

Drought from late spring to early summer can be devastating to white clover production. Hoglund (1985) reported a 75% loss of white clover production in two successive years at Lincoln Christchurch, and Brock (1988) reported a 75% loss of white clover production in 2 successive years from a spring drought in Palmerston North.

2.2.6 Herbage Production

White clover is commonly grown with perennial ryegrass in temperate regions (Frame and Newbould, 1968), which has resulted in research on herbage yields to be conducted mainly on the combination of the two sward species rather than in mono-cultures. Suckling (1960) recorded a mono culture of white clover producing 10.55 tons DM/ha for an unirrigated area. On a Winchmore irrigated trial the mean annual pasture production of a grass/clover sward was 10 160 kg DM/ha (Rickard and Radcliffe, 1976).

Cardus (1991) compared four white clover cultivars 'Grasslands Huia', 'Grasslands Pitau', 'Grasslands Tahora' and 'Grasslands Kopu' with four pre-release cultivars, G23, G26, G39 and G49 and 24 breeding lines. The 32 cultivars and breeding lines were transplanted into grass swards in autumn 1989 at two sites one of which was at Palmerston North. The Palmerston North site was mob stocked with sheep and the other site (Aorangi Research Station on the Kairanga Plains) was rotationally grazed by Friesian bulls. The general purpose cultivar 'Huia' made up 28% of a ryegrass/white clover sward in the grazing trial conducted at Palmerston North. Leaf density and leaf width of the 'Huia' cultivar were 4178/m^2 and 17.1mm respectively. Stolon growing point counts included all axillary buds with an open leaf. 'Huia' had a stolon growing point count of 1850/m^2. Leaf density and leaf width of 'Tahora' were lower than 'Huia' (3075/m^2 and 13.0mm respectively) but stolon production was higher than 'Huia' (2760/m^2). Dry weight of the 'Huia' and 'Pitau' cultivar white clovers were exactly the same 0.28g/m^2.

Ryan (1989) compared four white clover cultivars 'Grasslands Huia', 'Grasslands Tahora', 'Grasslands Kopu' and 'Grasslands Pitau' under two grazing managements; year round rotational grazing compared with rotational grazing incorporating a twelve week period of set stocking during spring. 'Huia' white clover was the best cultivar under both grazing managements. Mean annual dry matter production of 'Huia' white clover was 4350 kg DM/ha compared to 'Tahora' and 'Pitau' which were lower at 3550 and 3500 kg DM/ha respectively.

2.2.7 Grazing management

Plant size may influence productivity, persistence and fecundity of an individual within a plant population (Harper, 1977).

Many cutting studies have shown that the total herbage production from grass/white clover swards generally increases as the interval between defoliation is lengthened (Frame and Newbould, 1986).

In Southland, Hay and Baxter (1984) indicated that the more frequent grazing during set stocking in spring increased the number of growing points and stolon number. Stolon weight in August to December was only increased in set stocking systems (22%). Set stocking causes continual removal of the leaves from the white clover which can change its phenotype by increased branching and growing points. Under rotational grazing, losses in stolon dry weight may occur over the spring period because the infrequent severe defoliation causes higher levels of shading by grass which would inhibit branching.

The ability of white clover to tolerate grazing is related to morphological characteristics of the plant. Small leaved, densely stoloniferous white clover populations generally have a lower yield in pure stands, but greater persistence and productivity when grown with grass compared with large leaved populations (Widdup and Turner, 1983). Results of Brock (1988) and Hay, Brock and Fletcher, (1983), show that stolons in set stocked pastures were thinner and more branched than rotationally grazed pastures. Small leaved white clover varieties are more tolerant of intensive sheep grazing because the shorter petioles keep a greater proportion of leaflets below the grazing horizon. The small leaved varieties have a more extensive network of branched stolons which results in considerably more leaves per unit area than large leaved varieties (Korte and Parsons, 1984). Under continuous grazing large leaved cultivars may fail to persist unlike the smaller leaved types (Curll and Wilkins, 1981; Brock, Caradus, Hay, 1989).

Korte and Parsons (1984), found that hard grazing (residual herbage mass, 470 kg DM/ha) with sheep reduced the proportion of clover weight in the swards compared to lax grazing (residual herbage mass, 2010 kg DM/ha) at all grazing dates. The reduction in proportion of white clover was attributed to a reduction in weights of leaflets, petioles and internodes on each stem. The number of leaves per stolon and the number of stolons per unit area were little affected by the grazing treatment. The length of stolons per unit area and individual weight were both considerably greater in the lax than in the hard grazed areas.

Harris and Brougham (1968) found that rotational grazing produced plants with an erect growth habit and rooted stolons. In contrast, when continuously grazed, clover formed compact, prostrate plants. These differences in plant growth and morphology were attributed to differences in the light environment of different swards and to the removal of stolons by grazing.

.2.3 Effect of grazing management on the grass component

A grass plant consists of a number of tillers in close proximity and each tiller has axillary buds capable of developing further tillers. The number of tillers depends upon the relative rate of formation and death, while the dynamics of formation and death determine sward persistence and botanical composition. The rate at which tiller buds develop into visible tillers is determined by light and temperature (Langer, 1963). Increased herbage production of grasses may be attributed to increased tiller density and/or tiller weight (Hunt and Field, 1979).

Parsons, Collet and Lewis (1984), in a ryegrass sward in England, showed the number of tillers when continuously and severely defoliated. Severe defoliation resulted in a high tiller number (40 000 tillers/m^2) but the tillers have smaller leaf areas than those under continuos grazing. The sward managed by infrequent grazing or rotational grazing created swards with fewer tillers 10 000-15 000/m^2 but had larger leaf areas than under severe defoliation.

Results from Hunt and Field (1979) found that rapid tillering and increased leaf appearance commenced some four days after close grazing. The rate of new tiller appearance at 20°C was three times higher than at 10°C but dropped at 30°C. These studies at Palmerston North showed that tillering in perennial ryegrass was greatest in late winter or early spring, declined during reproductive growth and increased again during autumn. In contrast Hunt and Brougham and Harris (1967) reported a decline in tiller density of the sward during summer because of the failure of young tillers to become established.

Grazing management induces marked differences on plant structure. Hay, Brock and Thomas (1988) found the mean grass tiller density under set stocking (14500/m^2) was almost double that of rotational grazing (8000/m^2) even though both grazing treatments averaged 11500 kg DM/ha/yr. White clover growing point densities were more variable, year 1 set stocking 2200/m^2, rotational grazing 3600/m^2 and year 2 set stocking 3100/m^2 rotational grazing 1050/m^2. Mean grass shoot biomass was 50% greater in the shorter denser set stocked pastures (3500 kg/ha) than in the open taller rotationally grazed pastures (2400 kg/ha).

Hay (1983) studied a white clover ryegrass sward under rotational grazing and set stocking with sheep and found that aerial and surface stolons were maximised during summer and minimum during winter and spring. Buried stolons contributed a large proportion of total stolon weight throughout the year, ranging from 45% in summer to 95% in spring.

2.4 The grass/ legume interaction

A common difficulty with the grass legume sward is the competition from grass which limits later legume growth and persistence (Rhodes, 1981; Romero Yanez, 1985). Clovers are light demanding plants and this requirement plays an important role in competition between grass and clover swards (Black, 1960). Reduced light intensity or competition for light may reduce root growth and root:shoot ratio (Donald, 1958). Shading from grasses results in reduced nitrogen fixation through a loss of nodules, root decay and root growth (Ryle, Powell and Arnott, 1981). Clover varieties with long petioles and large leaflets are more capable of performing well in grass/clover mixtures if not severely grazed. Hunt and Brougham (1967) demonstrated that frequent and intensive grazing at different times of the year markedly influenced the growth and survival of pasture species, changing the botanical competition and ultimately herbage production.

2.5 Summary

Rhizomatous clovers are drought tolerant and winter hardy, and well suited for hill and high country environments. Rhizomatous clovers have shown a high level of persistence in environments where traditional legumes have often been unsuccessful. Herbage yields of rhizomatous clovers are similar to those of the more traditional clover species such as white clover but under extreme weather conditions and in low fertility soils rhizomatous clovers have the potential to out yield other clovers. Rhizomatous clovers are persistent under grazing, however the best grazing management for the rhizomatous clover particularly in New Zealand conditions has not been demonstrated. More research is required to evaluate the potential of rhizomatous clovers in medium to high fertility soils in low lying areas under a range of management practices.

White clover is adapted to a wide range of environments and is an important forage legume in temperate regions. It has a wide range of benefits in a pasture system however the most beneficial are its persistence under grazing due to its stoloniferous habit and its ability to supply nitrogen to the soil. The clover has a high feeding value and a medium to high level of productivity compared with other legumes used within pastures. Under grazing white clover shows a number of morphological responses depending on its genotype and frequency and intensity of grazing.

As well as changes in legume morphology differing grazing management systems can also influence the botanical composition of a ryegrass/white clover pasture. Tiller density and size of ryegrass is directly related to grazing management.

A large amount of research has been conducted on the individual components of the grass/clover sward too numerous to mention within this review, however aspects directly associated with the current field of study have been highlighted.

Chapter 3

Methods and Materials

3.1. Experimental site:

3.1.1. Location and Soil type

The grazing trial was located on the D2 block of the Plant Science Departmental Research Area at Lincoln University, Canterbury at latitude 43° 39S and longitude 172°28E.

The soil was a Templeton silt loam of variable depth, developed on fine alluvial sediments of the lower terraces of the Canterbury Plains. The A horizon was a fine sandy loam and is found to a depth of 30cm, the B horizon is mostly a loamy sand and sand texture ranging from 30 to 70cm deep. The 2C horizon starts at 70cm where there is some mottling, gravels are found from a depth of 80cm. It is a medium to free draining soil with a moderate capacity to retain moisture. The soil is commonly used for growing both crops and pastures which are primarily ryegrass/white clover swards. The nutrient status of the soil is medium, with soil quick-test analysis of samples taken on the 22 September 1993. Phosphorous (P) and magnesium (Mg) levels were satisfactory, while pH, sulphur (S), calcium (Ca), potassium (K) and sodium (Na) levels were low (Table 3.1).

Table 3.1. Soil Nutrient quick tests and pH of rep 1 and 2 of the grazing trial prior to the start of the grazing treatments in the spring of 1993.

Rep	pH	Ca	K	P	Mg	Na	S
1	5.4	5	4	17	16	4	3
2	5.3	6	4	14	17	4	4

3.1.2. Climate

Fig 3.1 shows the mean annual rainfall for the Lincoln area as measured by the Broadfields Meteorological station (Altitude 11.0m; Latitude 43 Deg 38min). The area is prone to drought and at the beginning of the experiment in late summer early autumn the area was just coming out of a drought situation. To compensate for a low autumn rainfall, 100mm of irrigation water was applied to all trial plots in early March and mid-April (Fig 3.1).

Mean air temperature decreased 11°C from the beginning of the trial period (late February) to mid -winter (late July). Mean air temperatures then increased from late winter to early spring. The mean grass minimum temperature for each month showed a steady decline from late summer (11°C) to July (-4°C). By September minimum mean grass temperature has risen to 2°C (Fig 3.2).

Mean soil temperatures over the duration of the experiment at depths of 0.1m and 0.3m were very similar. Mean soil temperatures showed a similar decline in temperature as the mean air and mean minimum grass temperature reaching a low in July of 4°C (Fig 3.3).

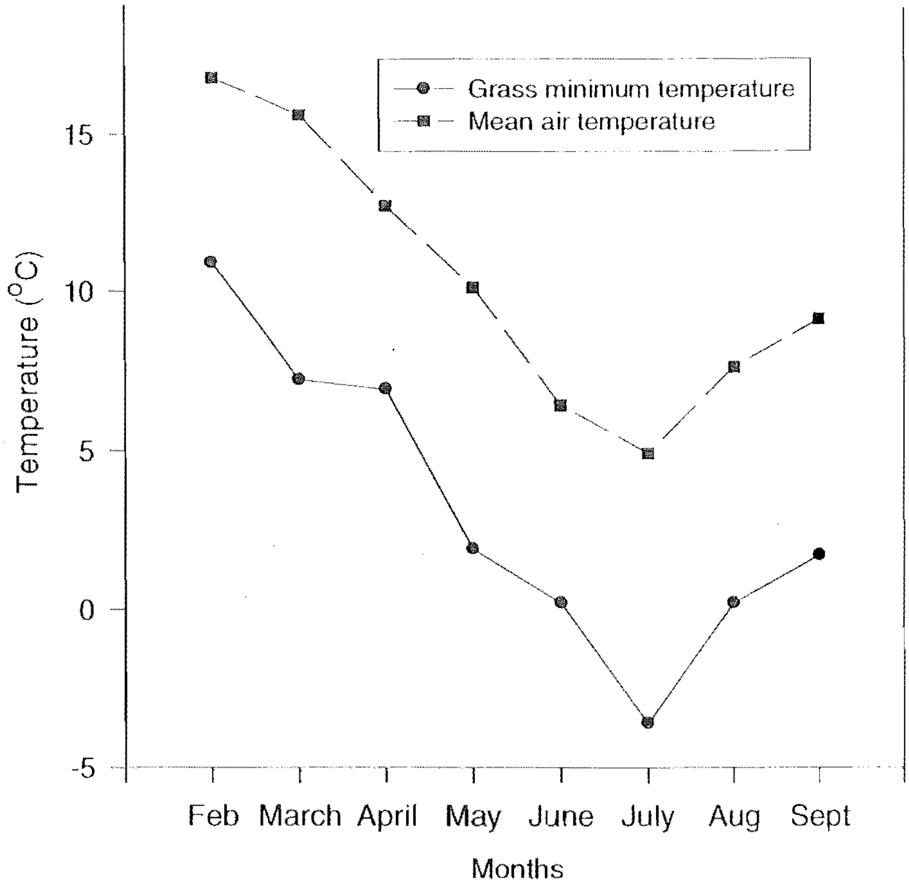


Fig 3.2 Monthly mean air temperatures and minimum grass temperatures as measured by the climate research unit Lincoln University.

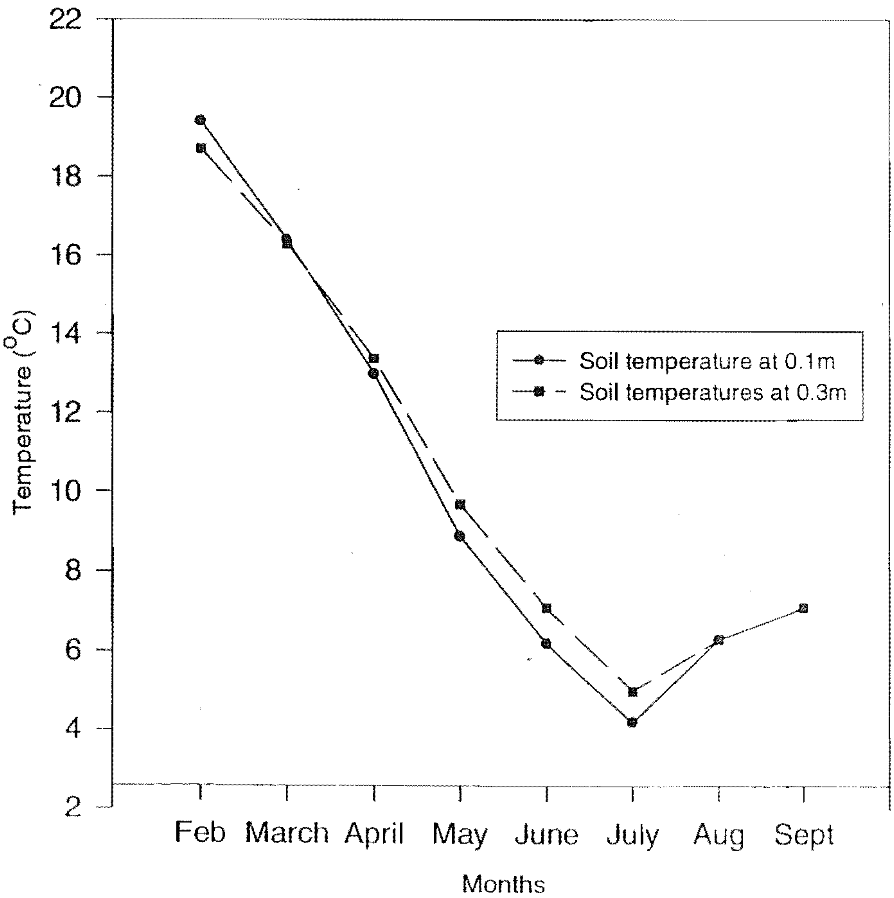


Fig 3.3 Monthly soil temperatures in 1995, as measured by

3.2 Site history

The rhizomatous clovers were originally sown on the 22nd of March 1989 within the site for seed production experiments (Gurung, 1993). Two cultivars / seed lines of Caucasian (*Trifolium ambiguum*; Plate 1.1 and zigzag (*Trifolium medium*; Plate 1.2) clovers were sown. The Caucasian cultivars Monaro and Alpine were sown as well as the zigzag seed lines Kentucky and Porters Pass (Appendix ; Plates 1.1 and 1.2).

The initial experimental design was a randomised block design with three replicates. Seeds were sown by cone seeder at 1cm spacing (100 seeds per m). There were three blocks; each block was considered as one replicate which comprised four plots. Each plot was 80m * 3.75m and consisted of four row's 0.75m apart there was a 1.5m gap between each plot.

Attempts were made in 1989/90 and 1990/91 to keep the plots free of weeds and white clover (*Trifolium repens*), however herbicide treatments against white clover were unsuccessful and subsequent zigzag and Caucasian growth was retarded. In the spring of 1992 high endophyte Marsden ryegrass (*Lolium perenne*) was direct drilled over the area, including the four row plots of rhizomatous clovers. In the spring of 1993 volunteer white clover was abundant and evenly distributed throughout the site. Volunteer red clover (*T. pratense*) was also present but to a lesser extent compared to the white clover (Plate 1.3).

The grazing trial was set up and fenced in August 1993. Grazing treatments were applied in September 1993 to obtain grazing heights outlined in 3.3 of this chapter. Two months after the grazing treatments were applied clover measurements were started. Rotationally grazed treatments were applied every 28 days during the growing seasons of 1993/94 and 1994/95. All treatments during the winters of 1994 and 1995 had intensive clean up grazings every 6 weeks. During October to December 1995 grazing treatments were stopped to allow a biological assay of the previous growing season (Moorhead *pers comm*) and grazing ceased after a clean up grazing in December 1995.

3.3 Experimental design of grazing experiment

3.3.1 Experimental design

The trial was a randomised block factorial design grazing experiment with eight main plots (10m * 45m) separately fenced across the three replicates of the four clover seed lines / cultivars. Within the eight main plots there were two blocks (replicates) with four grazing treatments in each block. The four grazing treatments had two levels of grazing frequency known as set stocked or rotational grazed and two levels of intensity, lax or hard (Plate 3.1).

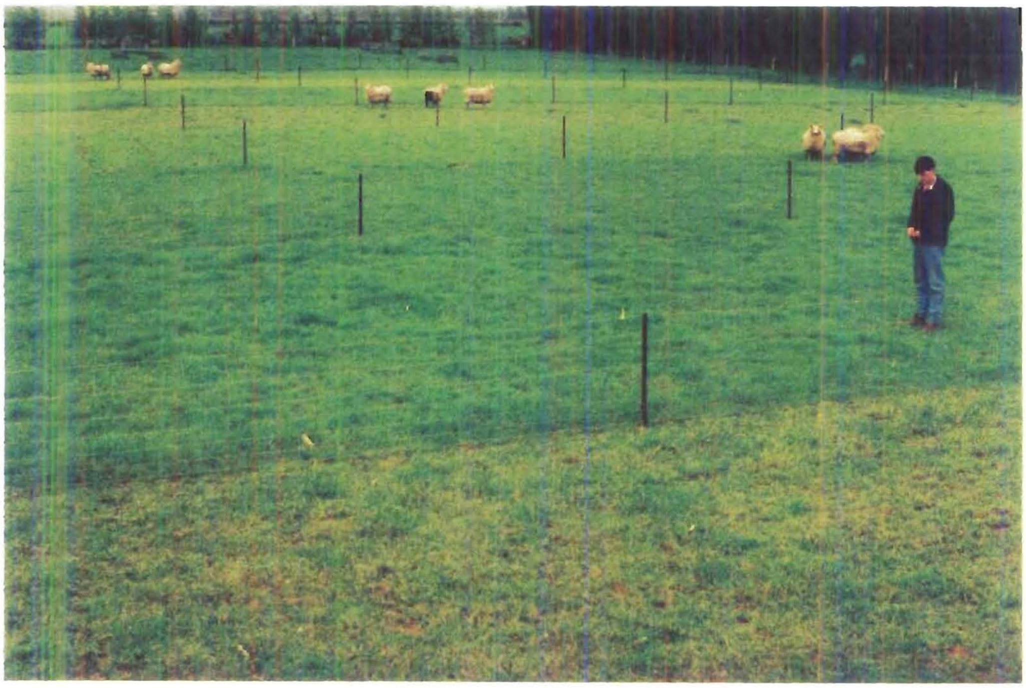


Plate 3.1 The grazing trial; fore-ground is the set stocked hard treatment (plot1), sheep at the far top are in plot 8 (set stocked lax).

Each grazed plot was further subdivided into 12 sub-plots. Within each sub-plot there were four rows of sown Porters Pass zigzag, Kentucky zigzag, Monaro Caucasian or Alpine Caucasian clovers. Because of the original design for the 1989 seed production experiment the subplot level was a strip plot design with three replicates rather than a split plot design because the sub-plots were not independently randomised within each main grazing plot (Appendix 2)(Plate 3.1).

Grazing treatments were first applied in early February, then on the 21st of March 1995 to allow expression of the grazing treatment. Rotationally grazed treatments were then applied at 25 day intervals after the second grazing (Table 3.2). The aim of the lax rotationally grazed treatments was to have a pre herbage grazing mass of 2000 to 3000 kg/ha and a post herbage grazing mass of 1500 to 2000 kg/ha). Hard rotationally grazed pastures aimed to have 1500 to 2000 kg /ha pre-grazing herbage mass and 700-800 kg/ha residual (Plate 3.2). Hard set stocked pastures aimed to maintain a herbage mass between 600 to 800 kg/ha and lax set stocked pastures at about 1700 kg/ha (Plate 3.3). To obtain the correct pasture height the put and take method was used.

Table 3.2 The applied grazing treatments; grazing interval, length of grazing and the number of sheep within the grazing treatments.

	Average interval between grazing	Average length of grazing	Average number of sheep within the grazing treatment
Rotationally Grazed Hard (RH)	25 days	4-5 days	22
Rotationally Grazed Lax (RL)	25 days	3-4 days	22
Set Stocked Hard (SH)	2.5 days	4.5 days	3-4
Set Stocked Lax (SL)	4.5 days	2.5 days	3-5

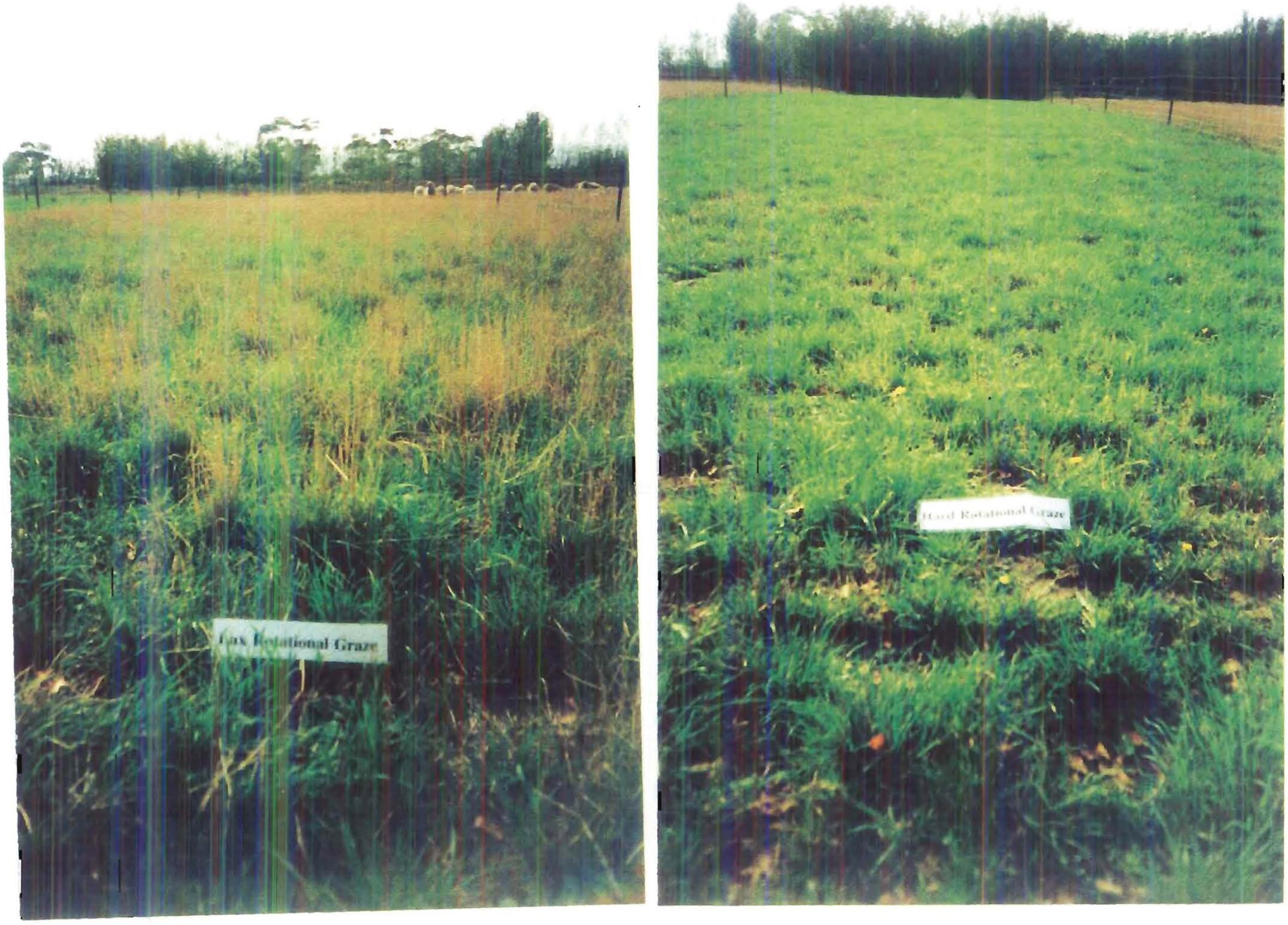


Plate 3.2 Lax (plot 2) and hard (plot 4) rotational grazed treatments, 10th of April 1995.

Plate 3.3 Lax (plot 1) and hard (plot 3) set stocked grazed treatments, 10th April 1995.

3.3.2 Composition of pasture before initial grazing

Grazing of the trial plot area had not occurred since late December 1994, so the grazing treatments were first applied in February 22nd.

A visual assessment of the grazing treatments before grazing in February, gave an indication of growth and vigour of the rhizomatous clovers (Appendix 3).

Botanical composition of the pasture before the March grazing treatments were applied are presented in table 3.3. Hard grazing treatments had a high proportion of bare-ground 20-24% and reduced the grass cover percentage. Set stocked lax pastures had little bare ground and about 80% grass cover. The highest proportion of rhizomatous clovers was in hard rotationally grazed pasture (9%).

Table 3.3 Botanical composition of the grazing treatments prior to the commencement of grazing in March 1995. Presented are the percentage point analysis hits for each plant species.

		Grazing	Treatment	
Species	SH	SL	RH	RL
Grass	58	80	56	74
Rhizomatous Clover	6	4	9	8
Red Clover	2	0	2	2
White Clover	7	5	7	2
Bare Ground	20	8	24	12
Weed	7	2	2	2
Dead Material	0	1	0	0

3.4 Grazing measurements

Botanical composition of the pasture, clover characteristics and ryegrass characteristics were measured the day before grazing. Grazing occurred on the 15th of April, 10th of May, 3rd of June and the 1st of October. Between the 3rd of June and the 1st of October treatments were grazed to between 750 to 850 kg DM /ha every six weeks.

3.4.1 Botanical composition of the pasture

Vegetative cover was assessed by using the point score technique to access the botanical response of the pastures to the grazing treatments by recording 'cover hits' or first hits for all botanical species (Radcliffe and Mountier, 1964) in addition to detached litter and bare ground. A string transect was used to bisect the main plots in half going across each sub-plot. The pointing apparatus a board which consisted of 20 nails, was placed in line with the transect across each row of the sown species, giving 80 hits per sub-plot and 960 hits for each main plot. Point analysis was done for both rotationally grazed and set stocked swards prior to grazing of rotational grazed treatments (ie every 25 days).

3.4.2 Clover Morphology

Clover characteristics were measured within each main plot the day before grazing of rotationally grazed plots.

3.4.2a Number of clover growing points per metre squared

The number of trifoliate leaves for each sown clover as well as the self sown white clover were measured for each sub-plot.

Sown clover samples were measured by placing 0.1m^2 quadrats across sown rows of clover species and then counting the number of growing points. A sample was taken for each species within each sub-plot. Number of trifoliate leaves per metre square was calculated by dividing the combined total of growing points from the four samples of each species by four then multiplying by 10.

The number of trifoliate white clover leaves were calculated in a similar method as the sown clover however the four samples were taken from between the 1.5m wide strips.

3.4.2b Individual clover morphology

For each clover species a measurement of petiole length and middle trifoliate leaf length was made within each sub-plot. Thirty individual clover specimens cut at ground height were randomly taken from each sown species within each main-plot. Individual white clover specimens were collected from the 1.5m strips. All clover specimens had their petiole length measured and their middle trifoliate length measure and recorded. Petiole length, middle trifoliate length was calculated by dividing each sample of clover species by thirty.

3.5 Grass characteristics

3.5.1 Tiller weight and percentage green and dead

Between replicates of the subplots in the main-plots three 0.1m^2 quadrats were cut to ground level. Each cut sample was mixed and divided into quarters. One quarter was further divided into green and dead material. Sampled material was then dried (green, dead and the other three quarters of the sampled material were dried separately) to a constant temperature at 70°C for 48 hours then weighed.

3.5.2 Tiller numbers

The number of live tillers per metre squared was determined by placing $0.01m^2$ quadrats between each replicate of subplot and counting the number of tillers within the quadrat. Four samples were taken for each sub-plot, then averaged, and multiplied by 100.

3.6 Statistical Analysis

The strip plot grazing experiment was analysed using the Genstat 5.2 statistical package. The analysis provided a table of means for treatments and species.

Botanical analysis data was presented with means and interactions for grass, white clover and Monaro/Alpine Caucasian clover. The other three rhizomatous clovers measured as well as bare ground, weed and dead material only have means presented due to an uneven binomial distribution of the data (had many zeros in the data due to the clover not being present) compared to the more frequently observed sward components.

Morphological descriptions of the clovers had the same uneven distribution of the data, due to a lot of the zigzag and Alpine Caucasian growing points having been eaten out in some grazing treatments. Means for all sown clovers as well as white clover are presented but only the Monaro Caucasian and white clover have been analysed for significant interactions. Analysis of white clover data has been based on the assumption that the volunteer white clover was evenly distributed throughout before the grazing trial started in 1993.

Grass characteristics was also analysed using the Genstat 5.2 programme.

3.7 Underground biomass assessment

A root biomass evaluation of two subplots within each main plot was conducted in early August 1995 to evaluate the root biomass beneath Monaro Caucasian and white clover plants. The third replicate of sub-plots at the western end of each main plot were left out of the evaluation due to the invasion of the plots by the shading effect of the populars on the western side.

Eight cores were taken per clover species within each sub-plot. A systematic sampling method was used. Two cores were taken from each row of Monaro in the eastern and southern replicates in all eight of the main plots. Samples were taken in a zigzag pattern 1m apart up the rows within the subplot. White clover samples were removed from inter-row grassed areas on the western side of the Monaro by the same method outlined earlier for the Caucasian cultivar.

Cores with a diameter of 50mm were taken from a depth of 100mm, thus each core took a volume of soil and plant material measuring $1.96*10^{-4} / m^3$. The eight cores from each species within each sub-plot were combined. The samples of eight were washed together and sorted for Monaro, white clover, grass and weed roots, stolons and rhizomes. Components from each sample were dried to a constant weight at 70°C for 24 hours then weighed.

Data was analysed using the Genstat 5.2 programme assuming a strip plot design with two reps and two sub-plots per rep.

3.8 Supplementary study to access the recovery of sown rhizomatous clovers and volunteer white and red clover after a severe grazing in May.

Past research has shown that Caucasian can survive at high altitudes due to a period of winter dormancy (Daly and Mason, 1985). White clover can grow up until the onset of winter or when soil temperatures were above 7°C (Chapman, 1983). The supplementary study was used to clarify the effects of temperature on individual plant characteristics of different types of clovers.

3.8.1 Experimental site and history

The experiment was initially carried out in the seed production plots the paddock D2 (48m * 10m) of the Lincoln University Research Farm (Plate.3.4)(see soil description 3.1) . Three month old plants established in November 1986 were transplanted within the plots in February 1987. Plants were planted at a 0.5m within row spacing and 1m inter-row spacing. In each plot there were five rows and 19 plants per row, giving a total of 95 plants per plot. In spring 1987 surrounding areas around the plots were over-sown with Chewing Fescue (*Festuca nigricans*) (Gurung, 1989). The plots had three harvests of seed taken from them, 1987, 1988 and 1989. Since the harvest of 1989 plots have been grazed approximately every eight weeks during the growing season with clean up grazings in early June.

3.8.2 Experimental design

The design of the experiment was a randomised design, with two replicates of four seed lines: Caucasian clover cultivars Alpine and Monaro and seed lines Porters Pass and Kentucky. Each replicate had four plots and each plot was 10m by 5m with an extra guard area 0.5m surrounding all plot boundaries (Plate 3.4). Within this guard area volunteer white clover (assumed to be 'Huia' white clover) and red clover were present. Each plot was pegged out in six randomly chosen places, and surrounding the plots a selected number of white and red clover populations were also pegged out, from which numbers of leaflets, size of leaflets and height of plants were recorded. Six samples ($0.1m^2$) of each species and/or cultivar were taken 0.2m north of the pegs found within and between plots.

Plate 3.4 Supplementary study trial plot. Note foreground is plot 1. Sheep grazed the area to a residual herbage mass of 450 kg DM/ha. Samples were taken 0.30m to the north of the white pegs, north is at the bottom of the picture.

3.8.3 Pasture composition

Botanical composition of the pasture was measured prior to grazing of the experiment on the 5th of May 1995. Table 3.4 presents the percentage first hits recorded for each plant species along a transect line. The transect line was run across the diagonal of each plot. The point analysis technique was used recording first hits. At the start of the experiment Monaro Caucasian was the only clover which covered 30% of the plots. White clover was also dominant in areas selected. The other four clovers measured (red, Porters Pass, Alpine and Kentucky clovers) covered less than 20% of the plot areas. The dominant weeds in most plots were self-sown white clover, mouse-ear chickweed (*Cerastium fontanum*) and Californian thistle (*Cirsium arvense*) which contributed over 80% of the weed population. Plots were grazed on the 5th of March 1995 to a herbage mass of about 450kg/ha. Clover morphology was measured at 12, 24 and 50 day intervals after grazing.

3.8.4 Clover morphology measurements:

Number of trifoliate leaflets per metre square was calculated by counting the number present within a $0.1m^2$ quadrat then multiplying by 10. Counts were made at 180mm north of the pegged areas. Within each quadrat ten individual clover specimens were removed and had their petiole lengths and middle trifoliate lengths measured. An average for each of the plots was calculated.

Photography was also used to evaluate regrowth of the clover. Three to four samples of individual clover specimens were removed at ground level at 12, 24 and 50 days from each plot and photographed. Photos compared the two Caucasian species to white clover, and another photo was taken using the same white clover specimens comparing them to the two zigzag specimens.

3.8.5 Statistical analysis

Data was analysed using the statistical anova programme Minitab 9 for windows. Data was analysed assuming that the white clover and red clover was evenly distributed outside the plots and that the white clover and red clover were plots 5 and 6 with plots 1 to 4 being the rhizomatous clover plots. The trial had two reps each with six plots.

Table 3.4 Botanical composition of the old seed plots before grazing on the 5th of May 1995. Data presented is the percentage hits out of 240 recorded for that plot.

Plot No.	Sown Clover	Red Clover	White Clover	Grass	Bare ground	Weed	Litter
Porters Pass							
1	29	0	13	32	0	26	0
6	32	0	14	29	0	21	4
Alpine							
2	12	0	38	40	0	10	0
8	12	3	16	53	4	7	5
Kentucky							
3	28	0	16	28	0	28	0
5	8	0	8	32	0	52	0
Monaro							
4	58	2	35	0	0	4	0
7	48	1	8	33	0	0	10

Chapter Four

Results

4.1 Botanical composition

4.1.1 Grass

Grazing treatments had an effect on the percentage grass cover prior to all dates of grazing. Hard grazing reduced the proportion of grass cover at all grazing dates compared to lax grazing treatments. Rotational grazing also reduced grass cover in late autumn (Table 4.1.1a).

Overall there was little variation in the grass percentage cover within the rhizomatous species. Grass cover was depressed by Monaro Caucasian clover cover in May (Table 4.1.1b).

Table 4.1.1a The effect of different grazing treatments on the percentage grass cover prior to grazing.

Grazing Treatment		**Pregrazing Dates**		
	15/4	**10/5**	**3/6**	**1/10**
SH	68.6	44.3	64.9	55.3
SL	83.3	74.3	83.8	68.9
RH	59.0	64.1	61.6	56.3
RL	72.5	80.3	80.1	72.0
Significance	**0.050**	**0.012**	**0.021**	**0.030**
SED	2.50	4.35	3.73	3.30
Significant Contrasts				
S vs R	**0.006**	**0.025**	0.282	0.437
L vs H	**0.003**	**0.005**	**0.006**	**0.008**
Interaction	0.145	0.113	0.956	0.685

Table 4.1.1b The effect of different rhizomatous species on the percentage grass cover prior to grazing.

Species		Pregrazing	Dates	
	15/4	**10/5**	**3/6**	**1/10**
Monaro	67.9	57.5	69.6	59.1
Alpine	68.3	65.0	73.4	63.9
Kentucky	72.5	67.0	72.9	56.3
Porters Pass	70.4	73.1	74.6	66.6
Significance	0.249	**0.002**	0.108	0.110
SED	2.23	2.14	1.70	3.30
Significant Contrasts				
Caucasian vs Zigzag	0.078	**0.001**	0.105	0.124

4.1.2 Rhizomatous Clover

Set stocking of pastures significantly (P<0.042) reduced the percentage cover of Caucasian clovers. Caucasian clover was on average highest in the rotational grazed hard treatments when compared to the lax treatment. Percentage cover of zigzag clover was very low at all pre-grazing dates regardless of treatment but lax rotational grazing favoured its survival after winter (Table 4.1.2a).

Monaro had the highest percentage cover when averaged out over all four grazing treatments with a peak of 26.5%, 21 days after grazing in April. Caucasian clovers had a significantly (P<0.01) higher percentage coverage than zigzag at all pre-grazing dates (Table 4.1.2b).

Table 4.1.2a The effect of different grazing treatments on the percentage cover of Caucasian and zigzag clover prior to grazing.

CC = Caucasian clover ZZ = Zigzag clover

Grazing Treatment	Pregrazing Dates 15/4 CC	15/4 ZZ	10/5 CC	10/5 ZZ	3/6 CC	3/6 ZZ	1/10 CC	1/10 ZZ
SH	6.0	0.0	13.0	2.3	2.3	0.0	4.8	0.0
SL	6.1	0.0	12.9	0.1	3.5	0.0	5.3	0.0
RH	23.1	0.9	29.3	2.3	15.4	0.3	14.3	0.0
RL	18.4	0.8	17.9	1.9	7.6	0.0	13.4	1.6
Significance	**0.010**	0.057	**0.042**	0.084	**0.004**	0.500	**0.019**	**<0.001**
SED	2.26	0.23	3.36	0.58	1.16	0.15	2.68	0.08
Significant Contrasts								
S vs R	**0.003**	**0.015**	**0.020**	0.115	**0.002**	0.391	**0.005**	**<0.001**
L vs H	0.240	0.761	0.093	0.059	**0.028**	0.391	1.000	**<0.001**
Interaction	0.224	0.761	0.097	0.115	**0.012**	0.391	0.694	**<0.001**

Table 4.1.2b The percentage coverage of rhizomatous clovers prior to grazing.

Species	Pregrazing Dates 15/4	10/5	3/6	1/10
Monaro	13.1	26.5	11.0	18.0
Alpine	8.1	10.0	3.3	1.0
Kentucky	1.5	2.3	0.0	0.0
Porters Pass	5.6	0.9	0.1	0.8
Significance	**0.034**	**<0.001**	**<0.001**	**<0.001**
SED	1.88	1.91	0.90	0.84
Significant Contrasts				
Caucasian vs Zigzag	**0.009**	**<0.001**	**<0.001**	**<0.001**

4.1.3 White clover

Percentage cover of white clover was not affected by grazing treatments in autumn. Both frequency and intensity of grazing had an effect on white clover pasture cover in October

(Table 4.1.3a). The significant interaction (P<0.001) occurred when the two extreme treatments (SH and RL) depressed white clover cover.

Table 4.1.3a The effect of different grazing treatments on the percentage cover of white clover prior to grazing.

Grazing Treatment		Pregrazing	Dates	
	15/4	**10/5**	**3/6**	**1/10**
SH	8.4	10.3	9.5	18.0
SL	8.8	11.4	8.5	24.3
RH	12.3	14.0	11.3	25.6
RL	9.9	7.5	9.6	13.8
Significance	0.551	0.339	0.282	**<0.001**
SED	2.61	2.96	2.56	0.46
Significant Contrasts				
S vs R	0.281	0.982	0.792	**0.024**
L vs H	0.638	0.286	0.137	**0.003**
Interaction	0.509	0.163	0.246	**<0.001**

White clover cover was depressed by Caucasian clover with Monaro generally causing the greatest reduction. By pre-grazing in October percentage cover of white clover had doubled in all rhizomatous species treatments compared to pre-grazing in June (Table 4.1.3b).

Table 4.1.3b The effect of different rhizomatous clovers on the percentage cover of white clover prior to grazing.

		Pregrazing	Dates	
Species	**15/4**	**10/5**	**3/6**	**1/10**
Monaro	8.8	4.4	6.6	14.5
Alpine	8.6	8.1	8.5	20.1
Kentucky	11.5	10.5	10.3	23.0
Porters Pass	10.4	11.4	9.6	24.1
Significance	0.121	**0.003**	0.415	0.116
SED	1.14	1.11	2.13	3.49
Significant Contrasts				
Caucasian vs Zigzag	**0.030**	**<0.001**	0.169	**0.046**

4.1.4 Bare-ground, red clover, weed and dead material

Set stocked hard treatments had a higher proportion of bare-ground cover 21 days after grazing in March and April. Prior to grazing in October little or no bare ground was present. Red clover had low cover values in all grazing treatments and the percentage cover of dead matter was also low. Hard grazing particularly in the set stocked treatment resulted in a high percentage of weed cover ranging from 12.5 to 24.1% (Table 4.1.4a).

Table 4.1.4a The effect of different grazing treatments on the percentage cover of bare-ground, red clover, weed and dead material prior to grazing.

Variate	Grazing Treatment	Pregrazing Date 15/4	10/5	3/6	1/10
Bare Ground	SH	4.3	25.4	2.5	0.0
	SL	0.0	1.3	0.5	0.0
	RH	1.3	0.1	13.0	1.0
	RL	3.1	1.3	6.6	0.5
Red Clover	SH	0.0	0.1	0.0	0.1
	SL	0.0	0.0	0.0	0.0
	RH	0.0	0.4	0.1	1.3
	RL	1.4	0.0	0.5	0.5
Weed	SH	16.0	12.5	21.9	24.1
	SL	3.4	3.1	2.0	4.1
	RH	5.4	5.9	5.9	8.4
	RL	2.9	2.4	2.3	5.6
Dead	SH	0.0	0.0	0.0	0.0
	SL	0.6	3.4	3.5	0.0
	RH	0.0	0.0	0.0	0.0
	RL	1.3	0.0	1.6	0.0

The percentage cover of bare-ground was similar between each of the sown clover treatments. Prior to grazing in October the level of bare-ground and dead material was very low in all treatments compared to other dates. Red clover cover was unaffected by sown rhizomatous clovers and did not exceed 1%. Weed cover ranged between 4 and 14% with no obvious pattern although Kentucky and to a lesser extent Alpine tended to have more weeds (Table 4.1.4b).

Table 4.1.4b The effect of rhizomatous species on the percentage cover of bare-ground, red clover, weed and dead material prior to grazing.

Variate	Sown Clover		Pregrazing	Date	
		15/4	10/5	3/6	1/10
Bare Ground	Monaro	4.6	5.6	5.3	0.8
	Alpine	6.3	7.9	5.4	0.3
	Kentucky	5.0	8.1	4.9	0.4
	Porters Pass	7.3	5.3	7.0	0.1
Red Clover	Monaro	0.1	0.0	0.0	0.3
	Alpine	0.4	0.4	0.5	0.8
	Kentucky	0.7	0.1	0.0	1.0
	Porters Pass	0.4	0.0	0.0	0.3
Weed	Monaro	4.8	4.1	6.8	7.4
	Alpine	7.5	5.6	8.4	14.0
	Kentucky	8.8	8.1	10.6	13.1
	Porters Pass	6.8	6.0	6.3	8.1
Dead	Monaro	0.1	0.8	0.6	0.0
	Alpine	0.6	1.0	0.8	0.0
	Kentucky	1.0	1.1	1.4	0.0
	Porters Pass	0.3	0.6	2.3	0.0

4.2 Clover Morphology Characteristics

4.2.1 Length of the petiole

Petiole length of rhizomatous and white clovers in lax rotational grazed swards were on average longer than in other treatments. White clover petiole length was affected by both the intensity and frequency of grazing prior to grazing in April and May. The length of the white clover petiole was generally longer than the rhizomatous clovers except pre-grazing in October. There was a steady decline in petiole length from pre-grazing in April to pre-grazing in June in rotational grazed swards and set stocked lax swards (Table 4.2.1)

Table 4.2.1 The effect of different grazing frequencies and intensities on the petiole length (mm) of white clover and the sown rhizomatous clovers immediately before grazing.

Note: 0 indicates that no leaves were found

Dates Grazed	Sown Clover	SH	SL	RH	RL	SED	Treatment significance S R	L H	Interaction
15/4	Monaro	14	39	30	70	34.6	0.402	0.274	0.789
	WC	22	53	61	131	16.0	**0.014**	**0.021**	0.189
	Alpine	12	38	32	67				
	P.P	16	38	38	67				
	Kentucky	24	27	27	57				
10/5	Monaro	19	28	15	51	3.6	**0.028**	**0.003**	**0.013**
	WC	19	41	24	79	9.2	**0.045**	**0.009**	0.083
	Alpine	0	14	17	50				
	P.P.	0	0	0	57				
	Kentucky	0	0	19	28				
3/6	Monaro	16	17	12	42	15.0	0.379	0.242	0.263
	WC	19	31	19	34	2.1	0.248	**0.003**	0.395
	Alpine	4	23	12	24				
	P.P.	0	0	0	0				
	Kentucky	0	0	0	0				
1/10	Monaro	95	53	72	63	24.5	0.718	0.221	0.404
	WC	64	66	74	81	20.2	0.440	0.781	0.881
	Alpine	0	0	23	56				
	P.P	0	0	0	51				
	Kentucky	0	0	27	43				

4.2.2 Length of the middle trifoliate leaflet of clover growing points.

Length of the middle trifoliate leaflet was on average longer in autumn in lax rotationally grazed swards. The leaflet length of Monaro doubled from pre-grazing in June to pre-grazing in October and white clover showed a similar increase of 3-4mm, but was 8mm shorter than the Monaro. Kentucky and Alpine when present had leaf lengths similar to Monaro (Table 4.2.2).

Table 4.2.2 The effect of different grazing frequencies and intensities on the length (mm) of the middle trifoliate clover leaf prior to grazing.

Note: 0 indicates that no leaves were found

Dates Grazed	Sown Clover	SH	SL	RH	RL	SED	Treatment Interaction S R	L H	Interaction
15/4	Monaro	10	16	15	17	5.7	0.531	0.315	0.762
	WC	9	12	12	13	1.3	0.085	0.100	0.309
	Alpine	9	15	15	15				
	P.P.	11	9	15	19				
	Kentucky	9	11	12	16				
10/5	Monaro	10	14	9	20	1.0	0.131	**0.003**	0.068
	WC	9	10	9	15	0.9	0.052	**0.010**	**0.035**
	Alpine	0	5	11	15				
	P.P.	0	0	0	19				
	Kentucky	0	0	9	10				
3/6	Monaro	10	10	11	16	1.2	**0.032**	0.080	0.058
	WC	9	11	11	12	1.5	0.219	0.303	0.495
	Alpine	3	11	10	13				
	P.P.	0	0	0	0				
	Kentucky	0	0	0	0				
1/10	Monaro	24	23	24	24	2.5	0.793	0.861	0.728
	WC	14	13	14	14	0.8	0.789	0.239	0.444
	Alpine	0	0	23	22				
	P.P.	0	0	0	10				
	Kentucky	0	0	23	27				

4.2.3 Number of growing points (Trifoliate leaves)

Rotational grazing increased the number of rhizomatous clover growing points (number of trifoliate leaves). White clover growing points were highest in the hard rotationally grazed treatment compared to the other three treatments (Table 4.2.3).

Table 4.2.3 The effect of different grazing frequencies and intensities on the growing points (trifoliate leaves) of clovers per metre squared prior to grazing.

Note: 0 indicates that no leaves were found

Dates Grazed	Sown Clover	SH	SL	RH	RL	SED	Treatment significance S R	L H	Interaction
15/4	Monaro	270	500	640	890	139	**0.030**	0.089	0.950
	WC	140	490	530	410	131	0.204	0.297	0.088
	Alpine	70	220	730	510				
	P.P.	30	20	140	50				
	Kentucky	40	40	100	50				
10/5	Monaro	240	550	1320	1100	476	0.096	0.879	0.470
	WC	400	480	780	340	166	0.160	0.555	0.054
	Alpine	0	100	720	710				
	P.P.	0	0	0	40				
	Kentucky	0	0	0	50				
3/6	Monaro	100	450	670	430	172	0.108	0.682	0.094
	WC	200	380	410	290	204	0.683	0.840	0.375
	Alpine	30	350	290	170				
	P.P.	0	2	10	200				
	Kentucky	0	0	0	30				
1/10	Monaro	290	280	980	1360	119	**0.002**	0.102	0.118
	WC	320	460	650	330	75	0.150	0.187	**0.021**
	Alpine	150	120	140	100				
	P.P.	10	0	0	20				
	Kentucky	20	0	20	50				

The number of growing points for most treatments were lowest in June. Alpine had low growing point numbers in October but little difference between grazing treatments. The residual effects of grazing treatments on spring recovery showed a strong depression in Monaro set stocked leaf numbers and a significant interaction ($P<0.021$) for white clover where the extreme grazing treatments (SH and RL) had reduced leaf numbers (Table 4.2.3).

4.3 Grass Characteristics

4.3.1 Number of tillers

Laxly grazed pastures had higher tiller numbers than hard grazed treatments. Lax set stocked swards had the highest numbers of tillers ($5030-5750/m^2$) compared to the other three treatments. Tiller numbers in the set stocked hard swards were lower than the other three treatments, particularly before grazing in June (Table 4.3.1).

Table 4.3.1 The effect of different grazing frequencies and intensities on the ryegrass tiller numbers per m^2 prior to grazing.

Dates Grazed	SH	SL	RH	RL	SED	Treatment Significance S R	L H	Interaction
15/4	2930	5550	3980	4630	145	0.553	**<0.001**	**0.002**
10/5	4120	5630	4180	4500	825	0.410	0.222	0.404
3/6	2500	5030	3200	4800	80	**0.024**	**<0.001**	**0.004**
1/10	4150	5750	5700	5710	780	0.337	0.235	0.216

4.3.2 Dry weight of tillers

Lax grazed treatments prior to grazing in April, May and June had a significantly ($P<0.024$) higher proportion of tiller mass than hard grazing treatments, however over all treatments there was a steady decline in dry matter production from April to June. Frequency of grazing had little effect on the accumulation of dry matter. Prior to grazing in October the amount of tiller dry matter was affected by both frequency and intensity of defoliation. High pasture mass in the lax set stocked prior to grazing in October is due to the winter active weed *Poa* *annua*. High proportions of the tiller dry matter in the set lax grazed treatments was dead material (Table 4.3.2).

Table 4.3.2 The effect of different grazing frequencies and intensities on the weight of ryegrass dry matter (g DM per m^2) and percentage fresh matter prior to grazing. Herbage was cut and removed leaving a residual of 450 kg DM/ha .

Dates Grazed	SH	SL	RH	RL	SED	Treatment Significance S R	L H	Interaction
15/4 Weight	88	305	152	238	61.0	0.973	**0.039**	0.224
FW%	86	66	100	78				
10/5 Weight	13	118	41	112	8.0	0.137	**<0.001**	0.061
FW%	94	73	100	88				
3/6 Weight	20	73	17	42	12.9	0.165	**0.024**	0.230
FW%	96	85	100	95				
1/10 Weight	172	139	144	165	6.7	0.910	0.291	**0.012**
FW%	95	100	100	100				

4.3.3 Length of ryegrass tillers

Length of ryegrass varied from 39mm to 183mm. Lax grazing treatments generally had longer tillers than hard grazed treatments. Tillers in hard set stocked pastures were 50% shorter than in any other treatment. By pre-grazing in October the length of tillers was very similar for all treatments (Table 4.3.3).

Table 4.3.3 The effect of different grazing frequencies and intensities on the length (mm) of ryegrass was measured prior to grazing, measured from ground level to the top of the tiller.

Dates Grazed	SH	SL	RH	RL	SED	Treatment Significance S R	L H	Interaction
15/4	51	137	56	105	14	0.278	**0.007**	0.157
10/5	39	98	93	153	13	**0.009**	**0.007**	0.960
3/6	43	138	57	109	22	0.659	**0.017**	0.265
1/10	147	151	163	183	16	0.112	0.357	0.514

4.4 Underground biomass

4.4.1 Grass underground biomass

Underground biomass of grass was highest in set stocked lax swards (328g/m^3), but variation between treatments was small (Table 4.4.1a). The underground biomass of grass in Monaro treatments was 29% lower than in white clover treatments (Table 4.4.1b). A high proportion of the grass was the annual grass *Poa annua*.

Table 4.4.1a The effect of different grazing treatments on underground biomass (g/m^3) of grass in August 1995.

Grazing Treatment	Underground Biomass (g/m^3)
SH	250
SL	328
RH	218
RL	279
Significance	0.459
SED	62.5
Significant Contrasts	
S vs R	0.426
L vs H	0.210
Interaction	
	0.860

Table 4.4.1b The effect of white clover and Monaro Caucasian clover on under-ground biomass (g/m^3) of grass in August 1995.

Species	Underground Biomass (g/m^3)
Monaro	223
White Clover	315
Significance	0.081
SED	62.5

4.4.2 Monaro underground biomass

Set stocked treatments significantly reduced (P<0.007) the underground biomass of Monaro Caucasian clover. The most biomass was found under the rotationally grazed hard treatments (Table 4.4.2a).

Table 4.4.2a The effect of different grazing treatments on underground biomass (g/m^3) of Monaro Caucasian in August 1995.

Grazing Treatment	Underground Biomass (g/m^3)
SH	50
SL	106
RH	373
RL	270
Significance	**0.022**
SED	49.8
Significant Contrasts	
S vs R	**0.007**
L vs H	0.486
Interaction	0.123

There was no Monaro present in the white clover treatments. The average underground biomass for Monaro was 202 g/m^3 (Table 4.4.2b).

Table 4.4.2b The effect of white clover and Monaro Caucasian clover on underground biomass (g/m^3) of Monaro Caucasian in August 1995.

Species	Underground Biomass (g/m^3)
Monaro	202
White Clover	0
Significance	**<0.05**
SED	7.6

4.4.3 Underground biomass of white clover

Set stocked treatments had at least 80% more white clover underground biomass than rotationally grazed swards (Table 4.4.3a). There was less difference in the biomass under white clover and Caucasian treatments (Table 4.4.3b).

Table 4.4.3a The effect of different grazing treatments on underground biomass (g/m^3) of white clover in August 1995.

Grazing Treatment	Underground Biomass (g/m^3)
SH	20
SL	34
RH	4
RL	4
Significance	0.065
SED	4.1
Significant Contrasts	
S vs R	0.079
L vs H	0.061
Interaction	0.072

Table 4.4.3b The effect of white clover and Monaro Caucasian clover on underground biomass (g/m^3) of white clover in August 1995.

Species	Underground Biomass (g/m^3)
Monaro	7
White Clover	9
Significance	0.065
SED	0.1

4.4.4 Underground biomass of weeds (Non grass and not clover)

Hard grazed treatments particularly set stocked treatments had a high underground biomass (9.8g/m^3) (Table 4.4.4a). Monaro treatments had a higher proportion of weeds compared to white clover (Table 4.4.4b). The dominant component of underground weed biomass was yarrow rhizome (*Achillea millefolium*) and storksbill (*Erodium cicutarium*).

Table 4.4.4a The effect of different grazing treatments on underground biomass (g/m^3) of weeds in August 1995.

Grazing Treatment	Underground Biomass (g/m^2)
SH	9.8
SL	0.4
RH	2.0
RL	0.8
Significance	0.117
SED	2.9
Significant Contrasts	
S vs R	0.165
L vs H	0.080
Interaction	0.137

Table 4.4.4b The effect of white clover and Monaro Caucasian clover on underground biomass (g/m^3) of weed in August 1995.

Species	Underground Biomass (g/m^3)
Monaro	4.7
White Clover	1.8
Significance	0.447
SED	2.41

4.5 Supplementary Study on clover recovery from a grazing on the 5th of May 1995.

4.5.1 Number of growing point (Number of trifoliate leaves)

Rhizomatous clovers and red clover had increasing numbers of growing points up until 24 days after grazing, and then level off from 24 to 50 days. White clover continued to increase from 0 to 50 days. Monaro Caucasian clover on average had the highest number of growing points but the high variation in the data means it was not significantly different to white clover at 24 and 50 days (Plate 4.1)(Table 4.5.1).

Table 4.5.1 The number of clover growing points per metre squared over 50 days after grazing on the 5th of May to a residual herbage mass of 450 kg DM/ha.

Clover Species	0		Days After 12		Grazing 24		50	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Porters Pass	100	40	480	10	540	90	40	90
Alpine	550	220	960	760	2010	640	2080	810
Kentucky	40	10	150	40	360	170	310	10
Monaro	850	180	4500	1570	4940	3030	5280	3220
White clover	560	100	2940	860	3330	1660	4790	690
Red clover	320	220	350	180	380	150	360	160
Significance	**P<0.05**		**P<0.05**		N.S.		**P<0.05**	

4.5.2 The length of the middle trifoliate leaf

Leaf length of the middle trifoliate was much the same for all clover species except the zigzag seed line Porters Pass which was 4mm shorter than the rest at the start of the experiment. At 12 and 50 days there was no differences between clovers. At 24 days however there was a significant difference (P<0.05) between the different types of clover, probably due to the Porters Pass having a short leaf length (8mm) and Monaro which had a long leaf length (15mm)(Plates 4.1 and 4.2)(Table 4.5.2).

Table 4.5.2 The average length (mm) of the middle trifoliate for clovers over 50 days after grazing on the 5th of May to a residual herbage mass of 450 kg/ha.

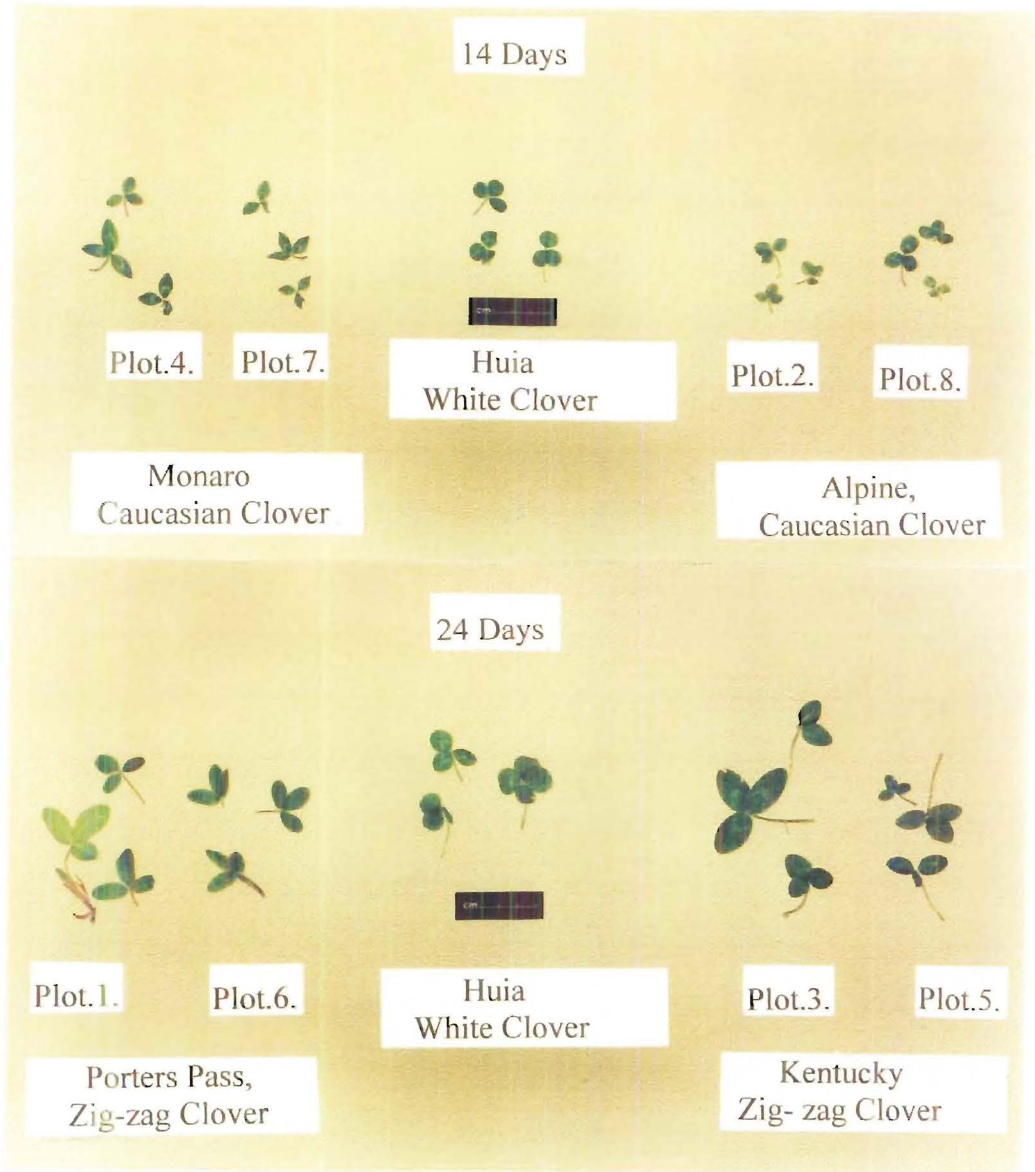
Clover Species	0		Days After 12		Grazing 24		50	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Porters Pass	6	2	10	4	8	2	9	1
Alpine	10	3	12	0	12	1	12	1
Kentucky	10	2	15	6	12	1	16	4
Monaro	11	1	16	1	15	3	15	1
White clover	10	1	11	0	10	1	12	0
Red clover	10	1	13	0	10	1	15	1
Significance	N.S.		N.S.		**P<0.05**		N.S.	

4.5.3 Petiole length

Grazing resulted in clover types having a similar petiole length at the start of the experiment. Twelve days after grazing Monaro Caucasian had extended its petiole length by an average of 71mm compared to white clover which was the next best at 46mm. Porters pass, Kentucky and red clover showed little increase in length from 24 to 50 days. White clover and Alpine Caucasian were the only clovers which steadily increased their petiole length over the entire 50 day period (Plates 4.1 and 4.2)(Table 4.5.3).

Table 4.5.3 The average petiole length (mm) for clovers over 50 days after grazing on the 5th of May to a residual herbage mass of 450 kg/ha.

Clover Species			Days After		Grazing			
	0		12		24		50	
	Date 5/5		Date 17/5		Date 29/5		Date 24/6	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Porters Pass	4	1	8	0	9	1	11	1
Alpine	3	1	16	8	34	11	43	18
Kentucky	3	1	6	1	8	2	5	1
Monaro	4	2	75	27	80	31	75	34
White clover	3	1	49	5	56	28	80	12
Red clover	4	1	25	15	22	6	32	7
Significance	N.S.		**P<0.01**		N.S.		**P<0.01**	



Day 50

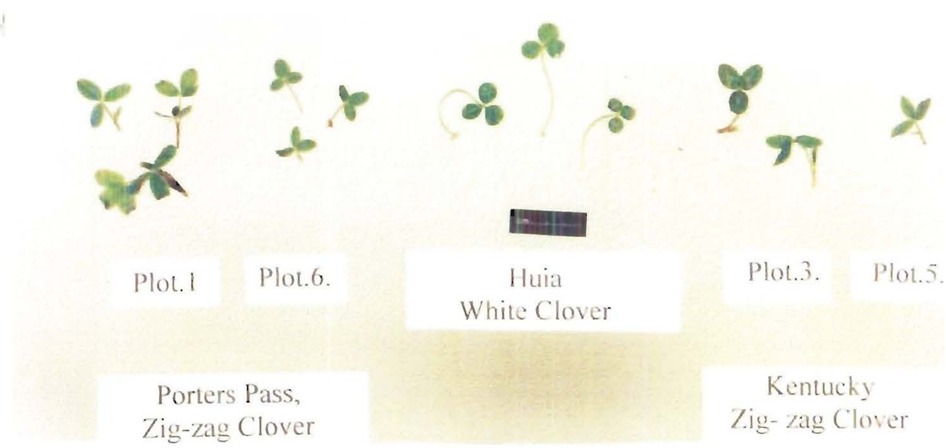


Plate 4.1 Kentucky and Porters pass zigzag clover and white clover 12, 24, 50 days after grazing the supplementary study plots on the 5th of May 1995, to a residual herbage mass of 450 kgDM/ha.

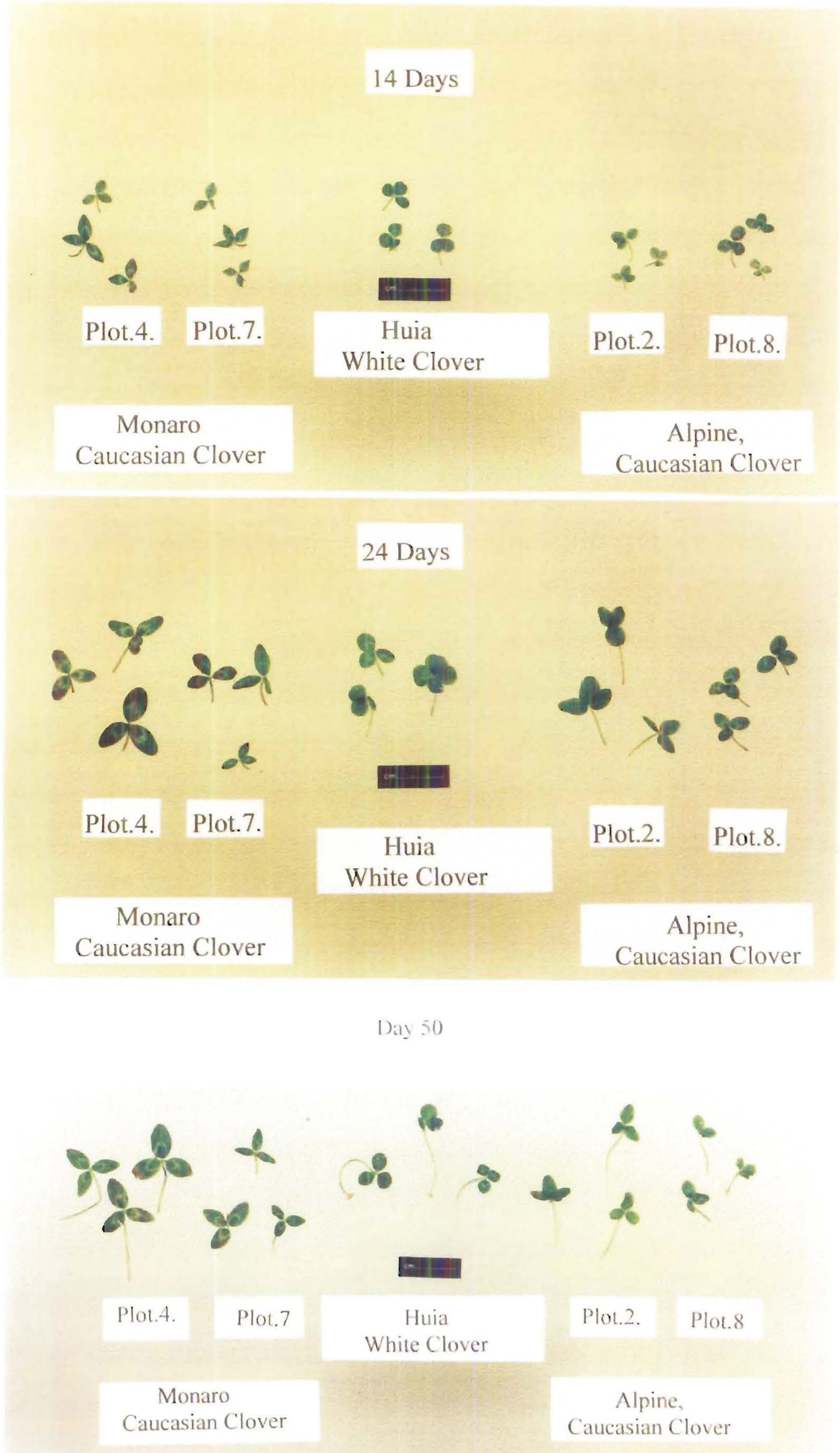


Plate 4.2 Monaro and Alpine Caucasian clover and white clover 12, 24, 50 days after grazing the supplementary study plots on the 5th of May 1995, to a residual herbage mass of 450 kgDM/ha

Chapter 5

Discussion

The main objective of this study was to describe the effect of different grazing treatments on the botanical composition of a sward and on clover morphology.

5.1 Botanical Analysis

5.1.1 Grass Cover

The present study showed grass was the most dominant of all pasture components, covering over 50% of the sub-plots, however Monaro Caucasian reduced grass cover by 10% (Table 4.1.1b). Hard set stocking also reduced the grass cover in all treatments at all grazing dates, and exposed bare ground for weed invasion. Weed cover was up to 29.1% in some of the sub-plots of the hard set stocked treatments. This was consistent with Chapman and McFarlane (1985) who also reported that hard grazing reduced the pasture density, and exposed bare-ground to weed invasion. Dominant weeds in the set stocked hard treatments were the rhizomatous weed yarrow (*Achillea millefollium*), the chickweed and storksbill.

Bare-ground also constituted a high proportion of sward cover ranging from 25.4% prior to grazing in May to 0% pre-grazing in October (Table 4.1.4a). These results conflict with those from Allan and Keoghan (1994) who showed that, ryegrass persistence was best under extreme grazing, and poor under lax grazing, when measured in October. This may be an artefact of the type of grazing used. The present experiment in the hard set stocked treatment was probably more extreme than Allan and Keoghan (1994), the hard set stocked treatment was grazed severely to less than 550 kg DM/ha, therefore removing most vegetative green material leaving little leaf to recover from.

5.1.2 Rhizomatous clover cover

Caucasian clover had a significantly ($P<0.009$) higher cover than that of zigzag in all grazing treatments (Table 4.1.2a). Zigzag clover has growing points above ground (Townsend, 1985), and these are susceptible to removal by grazing (Mason, 1987). Hard rotational grazing and to a lesser extent, lax rotational grazing produced a higher sub-plot cover of rhizomatous clovers than the set-stocked treatments (Table 4.1.2a). This supports Allan and Keoghans' (1994) conclusion that rotational and alternative grazing enhanced the spread of Monaro Caucasian at high or medium stocking rates compared to set stocking.

The average cover of hexaploid Monaro Caucasian was 5 to 18% (Plate 5.1) greater than in the diploid cultivar Alpine Caucasian prior to all grazing dates (Table 4.1.2b). Bryant (1974) and Dear and Zorin (1985) have also highlighted the greater potential of the hexaploid in mixed pasture swards as compared to the diploid Alpine. Vegetative cover of both Caucasian species was low prior to grazing in June than in May, probably due to declining temperatures. A similar reduction was measured by Mears (1975).

5.1.3 White clover cover

White clover cover was between 7 and 14% in all grazing treatments in autumn and early winter (Table 4.1.3a). The cover of white clover in pastures prior to grazing in October (14-26%) was similar to the proportions found by Caradus (1991) at Palmerston North for Huia white clover (28%) in mixed swards mob- stocked with sheep. After grazing in June 'clean up grazing' were applied every six weeks to leave a residual herbage mass of approximately 800 kg/ha. The white clover cover, prior to grazing in October in the lax rotational grazed

Plate 5.1 Cover of Monaro in the lax (plot 6) and hard (plot 7) rotational grazed treatments on the 25 of September 1995, approximately 5 weeks after the last grazing. Note the size of leaf and height of clover and the leafiness of the ryegrass in lax rotational grazed as compared to the hard rotational grazed, which had small leafed, short clover plants within the grass sward but still covered had a greater percentage cover than lax rotational grazed.

was low (Table 4.1.3a) which confirms work by Brougham (1958) that lenient and infrequent grazing favours grass growth and not white clover.

Set stocked treatments, were higher in white clover cover compared to the rotational grazed lax treatment(Table 4.1.3a). This supports Brougham (1958) who found that hard grazing favours the growth of clover. The severity of grazing in the present treatment in the hard set stocked (to an estimated residual of less than 550 kg DM/ha in May and June) was severe, leaving little leaf material post grazing, and therefore leaving few stolons from which leaves could develop over the winter. If the residual herbage mass of the hard set stocked treatment was increased it may have resulted in an increase in white clover coverage.

The cover of white clover in Monaro Caucasian sub-plots was reduced compared to the white clover sub-plots (Table 4.1.3b). Monaro cover in rotationally grazed pastures was high (Table, 4.2.1a) (Plate 5.1) and this reduced the potential for volunteer white clover growth.

5.1.4 Bare-ground, weed, red clover and dead material cover

Hard grazing treatments increased the proportion of bare ground (Table 4.1.4a), section 5.1.1. In rotational grazed pastures the drill rows were still present, and hard grazing left these rows visible, and the bare-ground between them susceptible to weed invasion (Table 4.1.4a).

The cover of red clover was very low in all treatments (Table 4.1.4b). Red clover was not sown in this trial, but the volunteer red clover that was present, was susceptible to grazing due to its above ground growing point.

Dead material was highest in the lax set stocked swards prior to grazing in April, May and June (Table 4.1.4b). Lax set stocking in autumn increased the proportion of less palatable grass material such as leaf sheath, inflorescences and dead material, due to sheep selectively grazing the more digestible components (Smetham, 1990). Clean up grazings in winter removed all dead material prior to grazing in October (Table 4.1.4 a and b).

5.2 Clover Morphology

5.2.1 Petiole length of clovers

Severe grazing of clovers, particular in set stocked hard treatments, resulted in reduced plant size. Caucasian clover particularly Monaro and white clover were more prostrate and compact in hard grazing treatments (Plate 5.1)(Table 4.2.2 and 4.2.3). Frame and Newbould (1986) suggested this response to grazing allows clover to escape defoliation as it is not in the grazing horizon.

Lax grazing increased the petiole length of all clovers (Plate 5.1). White clover petioles were substantially longer than the rhizomatous clovers (Table 4.2.1). To compete with grasses for light, clovers must produce long petioles and large leaflets (Brougham, 1962). Brock *et al* (1989) also found that stolon length was longest under rotational grazing.

Petiole length declined as autumn progressed for Caucasian clover and white clover. After the clean up grazing in winter and prior to grazing in October, petiole lengths for each clover were similar between treatments but longer than in autumn (Table 4.2.1a), which may have resulted from declining air and soil temperatures reducing elongation of the petioles. During the present trial mean soil temperatures at 0.1m in May and June was 9°C and 6°C respectively (Fig 3.3) and mean air temperature was 11°C in May and 7°C in June (Fig 3.2).. Munro and Hughes (1963) reported that petiole length is temperature and light dependent, particularly for white clover. Chapman (1983) measured little stem elongation in white clover from mid-June to mid-August in the field in New Zealand, when soil temperatures were in the range of 6.5-7.0°C. Dear and Zorin (1985) found *T.ambiguum* ceased growth in winter although a few short green leaves were evident reducing leaf size and trifoliate leaf number.

5.2.2 Middle trifoliate leaf length

Middle trifoliate leaf length of rhizomatous clovers were 2 to 10mm longer than white clover. Leaf lengths of all clovers were longer before grazing in April than June. Leaves were longest in the lax rotational grazed pastures (Plate 5.1)(Table 4.2.2). Widdup and Turner (1983) reported that severe grazing reduces leaf size, allowing small leaved clovers increased productivity and persistence than large leaved types. Infrequent grazing allows the expansion of clover leaves, which increases their potential to compete for light within the sward (Harris and Brougham, 1968), and thus maintains photosynthetic capacity (Curll and Jones, 1989).

The expansion of clover leaves is also sensitive to temperature and photoperiod. Low temperatures in autumn and winter may reduce leaf size in white (Brock *et al*, 1989; Haycock, 1981) and Caucasian clover (Mears, 1975).

5.2.3 Supplementary Study; growth of petiole and leaf after grazing

The supplementary study on regrowth of clover following grazing showed a similar temperature response to that of the main grazing trail. Decreasing temperature reduced the rate of growth of leaf and petiole structures, although petiole length of white clover continued to increase over the entire duration of the experiment. The Caucasian species, particularly Monaro, increased their petiole lengths for up to 24 days after grazing, but the rate of increase slowed from 24 to 50 days (Plate 5.2) suggesting that it was becoming winter dormant. Growth of the diploid Alpine Caucasian was slower than that of hexaploid Monaro Caucasian (Plates 4.1 and 4.2; Table 4.5.3).

Middle trifoliate leaf length increased in all species up until 12 days after grazing, but from then on the increase was less than 4 mm. Rhizomatous clover leaf lengths ranged from 6 mm for Porters Pass zigzag to 16 mm for Kentucky zigzag and Monaro Caucasian clover (Plate 5.2). This was below that recorded in the main grazing trail for these species pre-grazing in October which ranged from 10 mm for Porters Pass to 27 mm for Kentucky, 22 mm for Alpine and 24 mm for Monaro (Plates 4.1 and 4.2) (Table 4.2.2). Again, this indicates that temperature decreased leaf expansion of clover leaves from early May onwards.

5.2.4 Number of Growing Points

Hay and Baxter (1984), found that set stocking of pastures allows continual removal of leaves from white clover and this causes a change in clover phenology such as increases in branching and the number of growing points.

Hard set stocking of pastures until grazing in June, lowered growing point numbers of Caucasian clover by an average of 200% than in other treatments. Hard rotational grazing had higher number of growing points of both Caucasian and white clover at all grazing dates. White clover produced more growing points than Caucasian clover in set stocked hard treatments after grazing in autumn (Table 4.2.3). After clean up grazings were applied during winter pre-grazing growing point numbers in rotational grazed treatments were subtantially higher in Monaro Caucasian than in any clover (RH 980 and RL 1360/m^2). White clover however produced more growing points in set stocked treatments than in any other treatment prior to grazing in October (Table 4.2.3), similar results were found by Brougham (1957).

Dear and Virgona (1995) reported that once established, Caucasian clover plants tolerates grazing because the stems and growing points are below the soil surface. Compared to the zigzag clover which had very low populations of growing points (Table 4.2.3) because of growing points above ground (Townsend, 1985).

White clover growing point numbers were well below that recorded by Caradus (1991) for Huia white clover in a mixed sward at Palmerston North (1850 growing points/m^2). One of the main factors to consider in the interpretation of this data is that the white clover was self sown, unlike the rhizomatous species, and this may have resulted in low populations.

High growing point densities are expected to confer an advantage in persistence of white clover, because stolon production is essential for vegetative survival (Beinhart, 1963). Therefore frequent grazing may benefit white clover production.

5.2.5 Supplementary study on the growing point numbers of clovers after grazing.

Grazing to a pasture mass of 450 kg DM/ha removed most of the petioles that were present before grazing. By 12 days after grazing subtantially more growing points were present for Caucasian and white clover compared to the other clovers. Zigzag clover had low populations of growing points throughout the trial period, which probably resulted from their removal during previous grazing. Monaro had very high numbers of growing points from grazing to day 12, but low increases from 12 days after grazing to 50 days after grazing. White clover, however, continued to increase the number of growing points over the entire 50 days of the trial (Plate 5.2)(Table 4.5.1) suggesting growth of white clover can occur during cool temperatures. Brougham (1962) also showed continued leaf initiation and development by white clover throughout the winter at Palmerston North. Haycock (1981) reported that the rate of leaf appearance for white clover increased linearly with the temperature in the range 5-11°C which was similar to the mean average air temperatures in May for this trial. Dear and Zorin (1985), reported that decreases in temperature (Fig 3.1 and 3.2) resulted in higher root

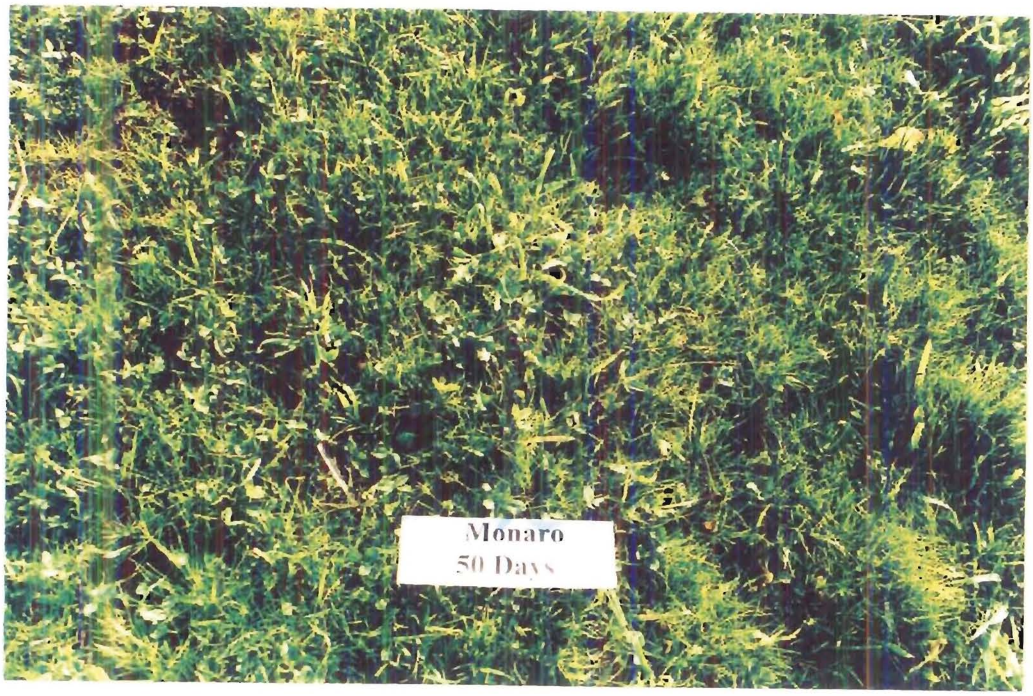


Plate 5.2 The cover of white and Monaro Caucasian clover 50 days after grazing on the 5th of May 1995 to a residual herbage mass of 450 kg/ha, in the supplementary study trial plots. Note trifoliate leaf populations and leaf size of clovers.

to shoot ratios for Caucasian clover, with a resultant reduction in the number of growing points. The hexaploid Monaro Caucasian had more growing points than the diploid Alpine (Table 4.2.3).

5.3 Grass Characteristics

5.3.1 Tiller number

Perennial ryegrass tiller numbers follow distinct seasonal trends, with highest numbers in late winter-early spring and lowest numbers in late autumn, however the rate of tillering and tiller numbers will also be influenced by grazing management (Hunt and Field, 1979; Korte, 1986; L'Huillier, 1987). In the present trial lax grazed pastures particular those run with a set stocked system, had more tiller numbers than hard grazed pastures until grazing in June (Table 4.3.1). Lax grazing in autumn allows sufficient leaf area to promote high pasture growth rates (Smetham, 1990).

Hard set stocking of pastures in April increased the number of tillers prior to grazing in May but a severe grazing in May reduced the number of tillers prior to grazing in June by 1600/m^2 (Table 4.3.1). When pastures are grazed hard, as inevitability occurs during a period of feed shortage, tiller death can occur. Pasture production, can therefore, be reduced for several months, until tiller numbers recover, allowing weeds to invade bare-ground patches (Korte, Chu and Field, 1987). Low tiller numbers in the hard set stocked treatment occurred prior to all grazings. However, tiller numbers recovered prior to grazing in October, compared to autumn and winter, but were still below the other treatments (Table 4.3.1). These reduced tiller numbers allowing invasion of the winter active grass *Poa annua*, chickweed (*Cerastium* *arvense*) and storksbill (*Erodium cicutarium*) and yarrow (*Achillea millefolium*) in the hard set stocked treatment.

5.3.2 Tiller weight and length

Results for the tiller weight and length followed a similar trend to tiller numbers. In hard set stocked treatments tiller weight and length were substantially reduced compared to the other treatments and both tiller weight and length were higher pre-grazing in April than in June. Lax grazed pastures had higher tiller weights and lengths than hard grazed pastures and lax set stocked pastures had a greater accumulation of dry matter than other pastures (40% more on average) (Tables 4.3.2 and 4.3.3).

Reduced tiller weight and length from April to June was probably caused by reducing soil and air temperatures. In the present trial mean air temperature from March to June declined from 15.5°C to 6°C and minimum grass temperatures declined from 7°C to 0°C (Fig 3.2). Mitchell and Lucanus (1960) reported a similar reduction in day temperature from 15.5 to 7.2°C caused a reduction in growth of individual tillers and that the length and width of leaf blades also declined with lower temperatures.

Low or no irrigation was applied to the grazing treatments from April to May (Fig 3.1) and this may have caused, low tiller weights and tiller length due to a lack of soil moisture. Moisture stress causes a reduction in tiller dry weight, because of a reduced rate of leaf expansion, slower rates of leaf appearance and accelerated rates of leaf senescence (Leafe, Jones and Stiles, 1977). This grazing experiment was on a silt loam of variable depth and visual observations suggest that growth in some areas of the trial, may have been restricted by low soil moisture.

5.4 Underground biomass

5.4.1 Monaro Caucasian underground biomass

Removal of plant leaf material is almost always associated with a drop in total (top and root) plant weight (Booysen and Nelson, 1975). Persistent forage legumes have the ability to maintain growing points and leaf area below grazing height and/or recruit new plants or shoots from seeds, stolons or rhizomes (Curll and Jones, 1989).

Underground biomass in early August of grass was reduced by hard grazing (Table 4.4.1a). Reduced leaf material, a result of intensive grazing (Tables 4.3.2 and 4.3.3), may have lead to a decrease in the under ground biomass of grass. Grass underground biomass was highest (315g/m^3) under white clover sub-plots compared to Monaro Caucasian (223g/m^3). Sward coverage (Table 4.1.2a), growing point numbers (Table 4.2.3) and underground biomass (Table 4.4.2a) were highest for Monaro in hard rotational grazed treatments, where grass cover was suppressed by Monaro (Table 4.1.1 a and b) suggesting that Monaro had a competitive advantage over high endophyte ryegrass in these treatments.

Severe defoliation removes growing points and leaves which are required for the production of assimilates (Forde, Hay, Brock, 1989; Peterson *et al*, 1994a). This in turn depletes the source of carbohydrates for growth (Sheaffer *et al* 1988; Peterson *et al* 1994b). The increased biomass under rotational grazing (322g/m^3); compared to set stocking (78g/m^3), indicates that long intervals between grazing are required to enable underground biomass to build up, particularly in the autumn period. Similar conclusions were reached by Allan and Keoghan (1994), Forde *et al* (1989) and Peterson *et al* (1994b) who all found that hard frequent grazing reduced the underground biomass of Caucasian clover.

5.4.2 White clover underground biomass

White clover produced the highest underground biomass in set stocked treatments, in contrast to Monaro which was highest in rotational grazed swards (Table 4.4.3a). The amount of underground biomass of white clover (9g/m^3) was substantially less than that of Monaro (202 g/m^3) in each treatment. Frequent defoliation stimulates stolon growth of white clover (Brougham, 1959), which is light sensitive, whereas long spells between grazing will shade stolons and reduce plant growth (Zaleski, 1970).

5.4.3 Weed underground biomass

Weed underground biomass was highest under hard grazed treatments (Table 4.4.4a), which supports the idea that the severity of grazing reduced grass and clover cover allowing the invasion of weeds into exposed bare-ground areas.

Monaro treatments had more underground weed material than white clover treatments (Table 4.4.4b). Reduced grass growth in Monaro Caucasian treatments may have allowed the invasion of weed material. A high proportion of the grass roots were that of the annual weed *Poa annua*. The main weed root was that of the rhizomatous weed yarrow and storksbill.

Chapter 6

General Discussion

6.1 Experimental problems

6.1.1 Experimental design

The grazing trial was restricted to the original design and area of the seed plots. The main grazing trial had only two reps of the different grazing treatments, in the ideal situation three or more reps would have been better suited so that significant differences between reps of grazing treatments and within grazing treatments can be clearly shown. Lack of randomisation between grazing treatments of sub-plots with the sown rhizomatous clover may have reduced the significance of the hypothesis being tested.

Grazing treatments only measured 56 * 10m which places limitations on grazing practices and method of sampling. Small plot areas reduced the potential to carry out rotational and set stocking grazing treatments due to a lack of forage for sheep, and changes in behaviour when animal numbers are low. The length of the sown rhizomatous clover row within the treatments was only 10m long but sampling could only occur on 7m metres of the row due to sheep walking up and down the fence lines and poking their heads through the fence and grazing the pasture on the other side, causing pasture growth variations immediately within the fence lines of grazing treatments.

6.1.2 Nutrient Transfer

Dung and urine are significant sources of N, P, K, Mg and Ca for pastures (Korte and Harris, 1987). Animals directly take up minerals through soil ingestion or indirectly through pasture ingestion. Very little of the ingested mineral is retained by the animal (<90%) and is excreted and the form of faeces and urine (McLaren and Cameron, 1990). The return of excreta stimulates herbage production and affects biological composition of the pasture by altering the balance between sward species (McIntyre and Davies 1952).

In the present trial there was a possibility that nutrients were being transferred between grazing treatments. Pasture ingested in one grazing treatment may have then been transferred to another in the form of excreta. This could be particularly important when animals are moved from lax grazed pastures into hard grazed pastures.

Another possibility is that nutrient transfer is occurring within grazing treatments. Animals defecate mainly at night resulting in the transfer of minerals particularly phosphate to camping sites (McLaren and Cameron, 1990). Animals avoid grazing in shaded areas such as the east end where shading occurred by the leguminous schrub Tagasaste (*Chamaecytisus palmensis*) in main plot 7 and 8 on the east side and by the populars on the west side, they also grazed more on the south side in plots 1-3 due. to human influence.

To clarify the effect of nutrient transfer, soil tests are required for all grazing treatments and for reps of sub-plots in grazing treatments. If an uneven distribution of nutrients becomes apparent from the soil tests, differential fertiliser application may be required to smooth out soil fertility differences.

6.1.3 Nodulation problems

During the duration of the trial it became noticeable that Caucasian clover plants particular Monaro were growing better at defecation sites, which suggests poor nodulation of the legume. Sowing of seed with suitable inoculum is vital to ensure nodulation of Caucasian clover. In the past nodulation of Caucasian clover has been poor but current research has identified bacterial strains This problem has been reported elsewhere and one that is currently being addressed (Lucas *per comms*).

6.2 Previous recorded results and further discussion

Results from the grazing trial were first collected in November 1993 to April 1994, measurements were made by botanical analysis conducted the same way as the present experiment.

Results showed that Monaro Caucasian was the superior rhizomatous species. Alpine Caucasian and the zigzag clover had a 10% lower coverage across grazing treatments compared to Monaro. There was very little difference between cover of the Alpine Caucasian and the zigzag clover (5 to 7%). This goes against the current data which shows that intensive grazing has removed most growing points of zigzag clover. The cover of Monaro was highest in hard rotational grazed treatments and lowest in the set stocked hard treatment a pattern found in the present trial. Grass cover in the hard set stocked treatments was about 50%, however unlike in the present trial weed invasion of bare-ground area was low due to the competition by Monaro Caucasian. The cover of rhizomatous clovers declined from November to April suggesting a temperature response (Moorhead *per comms*).

White clover cover was highest in set stocked treatments from January to April, a trend observed in the present study.

The spread of Monaro Caucasian has been very slow, approximately 15cm per annum (cover 11-26.5%; Table 4.1.2b) on either side of the sown row since planting in 1989, as compared to that measured by Allan and Keoghan (1994) who reported an average spread of 58.2cm across all rows, nine years after transplanting, This suggests that a combination of grazing, density grass roots and soil type are reducing the underground biomass of Caucasian clover.

White clover survives grazing by producing stolons that grow along the soil surface and weave their way around grass pseudostems. However Monaro Caucasian has to grow underground by penetrating the soil and the high endophyte ryegrass roots, thus reducing the potential to increase its spread which may be a problem in intensive grazing systems.

Does Caucasian clover fit into common grazing management practices in New Zealand ?

The main advantage of Caucasian clover is that the growing points are protected underground, its shows good drought tolerance and ability to withstand hard grazing by stock, rabbits and insect damage (Allan and Keoghan, 1994; Daly and Mason, 1985; Woodman, *et al* 1992). This mechanism of resistance may allow Caucasian clover to fit within common grazing practice.

Common farm grazing practice is to set stock in spring to reduce ryegrass reproductive growth and increase cover density, followed by lax infrequent grazing in summer to encourage white clover then a return to frequent close defoliation for a short period in mid to late autumn to reduce clover growth and promote winter ryegrass dominance (Brock *et al*, 1989). The present trial has shown that rotational grazing in winter was required to build up

Caucasian root biomass. Over the winter period it becomes dormant, then starts to regrow in spring when soil and air temperatures rise. Frequent grazing in spring of Caucasian clover may be required to reduce competition from grass and to increase the number of growing points. Thus the potential for Caucasian to fit into common farm management practices is good.

Where to with rhizomatous clovers from here?

Zigzag clover has shown promise in the South Island hill country of New Zealand (Mason, 1987) but the present grazing trail suggests it has little potential in moist lowland pastoral systems, due to the growing points being above ground.

Research in America by Peterson *et al* (1994) has highlighted the potential of Caucasian clover mono-cultures under different cutting and grazing practices, but this has not extended our knowledge on the potential of Caucasian clover in competition with competitive grasses. Work by Allan and Keoghan (1994), in the South Island hill country has shown that Caucasian clover can persist and spread in the hill country under extreme grazing pressure. When the present trial was initially set up the aim was to assess the potential of Caucasian clover in moist hill country environments. The aim of the present trial changed with the aim to access the autumn performance of rhizomatous clovers in moist lowland environments under different grazing practices. The results suggest that the hexaploid Caucasian may have a place in such environments, if managed correctly. Which conflicts with conclusions by Stewart and Daly (1980) , who reported that " it is doubtful whether *T.ambiguum* would ever be of much use in the lowlands".

Further research on Caucasian clover is required, to access its potential in the summer dry east coast and North Island hill and high country. Large areas of the east coasts of both main islands are drought prone, due to low rainfall and light soils. Therefore studies need to focus on the effects of seasonal temperature changes, irrigation and drought on Caucasian clover production, to access its potential in such environments especially in the presence of grass grub (*Costelytra zealandica*) and Argentine stem weevil (*Listronotus bonariensis*).

One of the problems with Caucasian clover is a lack of commercially available seed. Once the potential areas for pastoral production from mixed grass/Caucasian clover pastures becomes established in New Zealand and overseas, then the economic viability of sowing the crop increases, which results in more commercially available seed.

Chapter 6

Conclusions

1. The hexaploid Caucasian clover cv. Monaro was the best performed of the clover species in all grazing treatments, except white clover in hard set stocked treatments.
2. The hexaploid Monaro has shown slow rates of spread above and below ground since the trial started due to soil type, competition with high endophyte ryegrass and grazing treatments.
3. Alpine Caucasian clover (2n) in the past been shown to be more persistent than Monaro during drought, and in the present trial showed less sensitivity to grazing than the hexaploid Monaro.
4. Hard rotational grazing increased growing points and underground biomass of Monaro Caucasian compared to other grazing treatments, suggesting that long periods between grazing in autumn are required to build up underground biomass.
5. White clover was superior to Monaro Caucasian in hard set stock treatments, suggesting that rotational grazing shades stolons, and in effect reduces initiation and stolon development.
6. Zigzag did not perform well in a lowland moist environment under different grazing treatments.
7. Hard set stocking, reduced the number and growth of ryegrass tillers. It also reduced grass cover allowing an invasion of weeds into the exposed areas. Hard set stocking reduced the Caucasian clover cover.

Future Work

1. Identify the niche for Caucasian clover in production systems.
2. Continuation of the trial for at least two years so seasonal trends of the rhizomatous / ryegrass pasture can be observed.
3. Identify how Caucasian clover performs with other grasses, particularly Cocksfoot and Tall fescue.
4. Confirmation that the volunteer white clover is of a Huia type.
5. To measure and count the stolen number in different grazing treatments in grazing treatments.
6. Detailed soil tests are required to find differences in soil fertility between plots, so that variations can be flattened out by differential application of fertilisers between and within treatments.
7. To measure the production of Caucasian clover under irrigated conditions against non-irrigated.
8. A detailed study is required on Monaro, showing the effect of declining temperatures in a controlled environment on plant morphology characteristics.
9. Lamb growth rates on monocultures and/or grass mixtures of Caucasian clover in the New Zealand environment.

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References

ALLAN, B.E; KEOGHAN, J.M. 1994. More persistent legumes and grasses for oversown tussock country. *Proceedings of the New Zealand Grassland Association* **56**: 143-147.

ALLAN, B.E.; O'CONNER, K.F; WHITE, J.G.H. 1992. Grazing management of oversown tussock country 2. Effects on botanical composition. *New Zealand Journal of Agricultural Research* **35**: 7-19.

ARNOTT, R.A.; RYLE, G.J.A. 1982. Leaf surface expansion of the main axis of white and red clovers. *Grass and Forage* **32**: 227-233.

BEINHART, G. 1963. Effects of environment on meristematic development, leaf area and growth of white clover. *Crop Science* **3**: 209-213.

BLACK, J.N. 1960. The significance of petiole length, leaf area and light interception in competition between strains of subterranean clover (*Trifolium subterranean* L.) grown in swards. *Australian Journal of Agricultural Research* **11**: 227-291.

BOOYSEN, P de V.; NELSON, C.J., 1975. Leaf area and carbohydrate reserves in regrowth of tall fescue. *Crop Science* **15**: 262-236.

BROCK, J.L. 1988. Evaluation of New Zealand bred white clover cultivars under rotational grazing and set stocking with sheep. *Proceedings of the New Zealand Grassland Association* **49**: 203-206.

BROCK, J.L.; CARADUS, J.R.; HAY, M.J.M. 1989. Fifty years of white clover research in New Zealand. *Proceedings of the New Zealand Grassland Association* **50**: 25-39.

BROCK, J.L.; HAY, M.J.M.; THOMAS, V.J.; SEDCOLE, J.R. 1988. Morphology of white clover (*Trifolium repens* L.) plants in pastures under intensive sheep grazing. *Journal of Agricultural Science Cambridge* **111**: 273-283.

BROUGHAM, R.W. 1958. Leaf development in swards of white clover (*Trifolium repens*). *New Zealand Journal of Agricultural Research* **1**: 707-718.

BROUGHAM, R.W. 1958. Interception of light by the foliage of pure and mixed stands of pasture plants. *Australian Journal of Agricultural Research* **9**: 39-52.

BROUGHAM, R.W. 1959. The effects of the frequency and intensity of grazing on the pasture of short rotation ryegrass and red and white clover. *New Zealand Journal of Agricultural Research* **2**: 1232-1248.

BROUGHAM, R.W. 1962. The leaf growth of *Trifolium repens* as influenced by seasonal changes in the light environment. *Journal of Ecology* **50**: 449-459.

BROUGHAM, R.W.; HARRIS, W. 1967. Rapidity and extent of changes in genotypic structure induced in a ryegrass population. *New Zealand Journal of Agricultural Research* **10**: 56-65.

BRYANT, W.G. 1974. Caucasian clover (*Trifolium ambiguum* Bieb.) :- a review. *Journal of the Australian Institute of Agricultural Sciences* **40** : 11-19

CARDUS, J.R. 1991. Evaluation of elite white clover germplasm under rotational cattle and sheep grazing. *Proceedings of the New Zealand Grassland Association* **53**: 105-110.

CHAPMAN, D.F. 1983. Growth and demography of *Trifolium repens* stolons in grazed hill pastures. *Journal of Applied Ecology* **20**: 597-608.

CHAPMAN, D.F.; MC FARLANE, M. J.; 1985. Pasture growth limitations. *In* Using Herbage Cultivars, Grassland Research and Practice Series 3. New Zealand Grassland Association.

CHRISTIE, B.R.; CHOO, T.M. 1991. Registration of CRS-Z-1 zigzag germplasm. *Crop Science* **31**: 1716.

CURLL, M.L.; JONES, R.M. 1989. The plant-animal interface and legume persistence: An Australian perspective. p339-360. *In* G.C. Marten *et al.* Persistence of forage legumes. Proceedings of Australian/New Zealand/ United States Workshop, Honolulu, HI. 18-22 July 1988. ASA, CSSA, and SSSA, Madison, WI.

CURLL, M.L.; WILKINS, R.J. 1981. Effects of treading and the return of excreta on a perennial ryegrass-white clover sward defoliated by continuously grazing sheep. In: *Proceedings of the XIV International Congress*, Lexington, Kentucky. June 15-24, 1981. J.A. Smith and V.W. Hays (ed.), Lexington, Kentucky, U.S.A. : 456-458

DALY, M.R.; MASON, C.R. 1987. Performance of Caucasian and zigzag clovers. *Proceedings of New Zealand Grassland Association* **48** : 151-156

DAVIES, G.W.; EVANS, E. 1982. The pattern of growth in swards of two contrasting varieties of the white clover in winter and spring. *Grass and Forage Science* **37**: 199-207.

DEAR, B.S.; VIRGONA, J. 1995 Caucasian Clover-still waiting to achieve its potential. *The Proceedings of Annual Autumn Seminar, Central Branch, Grassland Society of New South Wales,* April 27 1995, (ed.) D.L. Michalk, New South Wales Agriculture Pasture Development Group, Agriculture Research and Vet Centre, Orange.

DEAR, B.S.; ZORIN, M. 1985. Persistence and productivity of *Trifolium ambiguum* M.Bieb. (Caucasian clover) in a high altitude region of south-eastern Australia. *Australian Journal of Experimental Agriculture* **25** : 124-132.

DONALD, C.M. 1958. The interaction of competition for light and for nutrients. *Australian Journal of Agricultural Research* **9**: 421-435.

ERITH, A.G. 1924. White clover (*Trifolium repens* L.) . *A Monograph.* London: Duckworth.

FAUST, N.; GASSER, H. 1980. Registration of C-20 zigzag clover germplasm. *Crop Science* **20**: 417.

FORDE, M.B.; HAY, M.J.M.; BROCK, J.L. 1989. Development and growth characteristics of temperate perennial legumes. p 91-109. *In* G.C. Marten *et al* (ed.) Persistence of forage legumes. Proceedings of Australian/ New Zealand / United States Workshop, Honolulu, HI 18-22 July 1988, ASA, CSSA, and SSSA, Madison, WI.

FRAME, J.; NEWBOULD, P. 1986. Agronomy of white clover. *Advances in Agronomy* **40**: 1-88.

GIBSON, P.B.; COPE, W.A. 1985. White Clover . In *Clover Science and Technology*, N.L. Taylor (ed.). Agronomy Series 25, American Society of Agronomy, Madison, Wisconsin: 471-490

HAGGER, R.J.; HOLMES, C.W.; INNES, P. 1963. White clover seed production in ryegrass/white clover swards. *Journal of British Grassland Society* **18**: 97.

HANSEN, N.E. 1909. The wild alfalfa's and clovers of Siberia with a perspective view of the alfalfa's of the world. *U.S. Department of Agriculture Bur. Plant Industries Bulletin* **150** 31 p. cited by Townsend, C.E. *et.al.* *Canadian Journal of Plant Science* **48**: 273-279.

HARPER, J.L. 1977. Population biology of plants. Biology of Plants. Academic Press London.

HARRIS, W.; BROUGHAM, R.W. 1968. Some factors affecting change in botanical composition in a ryegrass-white clover pasture under continuous grazing. *New Zealand Journal of Agricultural Research* **11**: 15-38.

HARRIS, W.; RHODES, I.; MEE, S.S. 1983. Observations on environmental and genotypic influences on the over-wintering of white clover. *Journal of Applied Ecology* **20**: 609-624.

HAYCOCK, R. 1981. Environmental limitations to spring production in white clover. In: Plant Physiology and Herbage Production. C.E. Wright (ed.). Occasional Symposium No. 13. British Grasslands Society, Hurley. pp 119-123.

HAY, M.J.M. 1983. Seasonal variation in the distribution of white clover (*Trifolium repens* L.) stolons among 3 horizontal strata in 2 grazed swards. *New Zealand Journal of Agricultural Research* **26**: 29-34.

HAY, M.J.M.; BROCK, J.L.; FLETCHER, R.H., 1983. Effects of sheep grazing and management on distribution of white clover stolons among 3 horizontal strata in ryegrass/white clover swards. *New Zealand journal of Experimental Agriculture* **11**: 215-218.

HAY, M.J.M.; BROCK, J.L.; THOMAS, V.J.; KNIGHTON, M.V. 1988. Seasonal and sheep grazing management effects on branching structure and dry weight of white clover plants in mixed swards. *Proceedings of the New Zealand Grassland Association* **49**:197-201.

HAY, R.J.M.; BAXTER, G.S. 1984. Spring management of pastures to increased summer white clover growth. *Proceedings of the Lincoln College Farmers Conference* **34**: 132-137.

HEALY, A.J. 1982. Identification of Weeds and Clovers 3rd edition Wellington; *Editorial Services* p299.

HELY, F.W. 1957. Symbiotic variation *in Trifolium ambiguum* M.Bieb with special reference to the nature of the resistance. *Australian Journal of Biological Sciences* **10**: 1-16.

HOGLUND, J.H. 1985. Grazing intensity and soil nitrogen accumulation. *Proceedings New Zealand Grassland Association* **46**: 65-69.

HOLLOWELL, E.A. 1966. White clover *Trifolium repens* L., annual or perennial? *Proceedings of the 10th International Grasslands Congress*, Helsinki, pp 184-187.

HUNT, L.A.; BROUGHAM, R.W. 1967. Some changes in the structure of a perennial ryegrass sward frequently but leniently defoliated during the summer. *New Zealand Journal of Agricultural Research* **10**: 397-404.

HUNT, W.H.; FIELD, T.R.O. 1979. Growth characteristics of perennial ryegrass. *Proceedings of the New Zealand Grassland Association* **40**: 104-113.

KANNENBERG, L.W.; ELLIOTT, F.C. 1962. Ploidy in *Trifolium ambiguum* M.Bieg. in relation to some morphological and physiological characters. *Crop Science* **2** : 378-382.

KHOROSHAILOV, N.G.; FEDORENKO, I.N. 1973. *Trifolium ambiguum* M.B. - a valuable fodder plant (Russian). *Tr.Priki Bot.Genet.Sel* **49** (1) : 64-80 cited by Stewart, A.V. and Daly, G.T. (1980) *New Zealand Journal of Experimental Agriculture* **8** : 255-259.

KORTE, C.J. 1986. Tillering in 'Grassland Nui' perennial ryegrass swards 2. Seasonal pattern of tillering and age of flowering tillers with two mowing frequencies. *New Zealand Journal of Agricultural Research* **29**: 629-638.

KORTE, C.J.; CHU, A.C.P.; FIELD, T.R.O. 1987. Pasture production. Livestock feeding on pasture. *New Zealand Society of Animal Production Occasional Publication No.* 10: 7-20.

KORTE, C.J.; HARRIS,W. 1987. Stolon development in grazed 'Grasslands Nui' perennial ryegrass. *New Zealand Journal of Agricultural Research* **30,** 139-48.

KORTE, C.J.; PARSONS, A.J. 1984. Persistence of a large leaved white clover variety under sheep grazing. *Proceedings of the New Zealand Grassland Association* **45**: 118-123.

LANGER, R.H.M. 1963. Tillering in herbage grasses. *Herbage Abstracts* **33**: 147-148.

LEAFE, C.L.; JONES, M.M.; STILES, W. 1977. The physiological effects of water stress on perennial ryegrass in the field. Proceedings XIII. International Grassland Congress, Leipzig, pp 253-260.

L'HUILLIER, P.J. 1987. Tiller appearance and death of *Lolium perenne* in mixed swards grazed by dairy cows at two stocking rates. *New Zealand Journal of Agricultural Research* **30**, 15-22.

LOBB, W.R. 1957. Zigzag clover may be of value in low rainfall areas. *New Zealand Journal of Agriculture* **94** : 183-184.

LUCAS, R.J. (Personal Communication) 1995.

LUCAS, R.J.; WHITE, J.G.H.; DALY, G.T.; JARVIS, P.; MEIJER, G.1980. Lotus, white clover, and Caucasian clover oversowing, Mesopotamia, South Canterbury. *Proceedings of the New Zealand Grassland Association* **44**: 47-53.

MC LAREN, R.G.; CAMERON, K.C. 1990. Soil Science: an introduction to the properties and management of New Zealand soils. Oxford University Press, Auckland.

MASON, C.R. 1987. Rhizomatous legumes for hawkweed dominated grasslands. *M.Agr.Thesis.* Lincoln College, New Zealand.

MC INTYRE, G.G.; DAVIES, J.G., 1952. Small plot studies in the evaluation of pasture intended for grazing. *Proceedings of the Sixth International Grasslands Congress*: 1361-1367.

MEARS, D.W. 1975. An evaluation of the phosphate and temperature requirements of *Trifolium ambiguum* M.Bieb. selections. *B. Agr. Sci.* Honours Thesis, Lincoln College, New Zealand.

MITCHELL, K.J.; LUCANUS, R. 1960. Growth of pasture species under controlled environment. II. Growth at various levels of constant temperature. *New Zealand Journal of Agricultural Research* **5**: 135-144.

MOORHEAD, A.J.E. (Personal Communication) 1995

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 establishment and first season growth of Caucasian clover. *Proceedings of the New Zealand Grassland Association* **56**: 91-95.

MUNRO, J.H.M.; HUGHES, R. 1966. White clover and hill land improvement. *Journal of the British Grasslands Society* **21**: 135-144.

OLLERENSHAW, J.H. 1983. Genetic variation in yield components of *Trifolium repens* at low temperature. *In*: Temperate Legumes. D.G. Jones and D.R. Davies (eds), Boston, Pitman Books Ltd, London. pp 89-100.

ORAM, R.N. 1990. Legumes: (Clovers). *Register of Australian Herbage Cultivars*: 155-161.

PALJOR, S. 1973. Agronomic evaluation of *Trifolium ambiguum. M.Agr.Sc. Thesis*, Lincoln College, University of Canterbury, New Zealand.

PARSONS, A.J.; COLLET, B.; LEWIS, J. 1984. Changes in the structure and physiology of a perennial ryegrass sward when released from a continuous stocking management: implications for the use of exclusion cages in continuously stocked swards. *Grass and Forage Science* **39**: 1-9.

PELLET, F.C. 1945. That new clover (*Trifolium ambiguum*). *American Bee Journal* **85**: 20-22.

PETERSON, P.R.; SHEAFFER, C.C.; JORDAN, R.M.; CHRISTIANS, C.J. 1994a. Responses of Kura clover to sheep grazing and clipping: 1. Yield and forage quality. *Agronomy Journal* **86**: 655-660.

PETERSON, P.R.; SHEAFFER, C.C.; JORDAN, R.M.; CHRISTIANS, C.J. 1994b. Responses of Kura clover to sheep grazing and clipping: 2. Below-ground morphology, persistence and total nonstructural carbohydrates. *Agronomy Journal* **86**: 660-667.

QUESSENBERRY, K.H.; TAYLOR, N.L. 1977. Interspecific hybridisation in *Trifolium* L. Sect. *Trifolium* Zoh. II. Fertile polyploid hybrids between *T.medium* L. and *T.sarosiense* Hazsl. *Crop Science* **17**: 141-145.

RADCLIFFE, J.E.; MOUNTIER, N.S. 1964a. Problems in measuring pasture composition in the field. Part 1: Discussion of general problems and some considerations of the point method. *New Zealand Journal of Botany* **2**: 90-97.

RHODES, I. 1981. The physiological basis of variation in yield of grass/clover mixtures. *In* Plant Physiology and Herbage Production. Occasional Symposium No. 13. British Grassland Society, Hurley, 149-151.

RICKARD, D.S.; RADCLIFFE, J.E., 1976. Seasonal distribution of pasture production in New Zealand XII. The Canterbury Plains. *New Zealand Journal of Experimental Agriculture* **4**: 329-335.

ROBERTSON, R.W.; ARMSTRONG, J.M. 1964. Factors affecting seed production in *Trifolium medium. Canadian Journal of Plant Science* **44** : 337-343.

ROMERO YANEZ, O. 1989. The effect of stocking rate on white clover morphology and yield. Unpublished Masters Thesis Lincoln College of Canterbury, Christchurch.

RYAN, D.L. 1989. White clover options for sheep-farming in southern regions of New Zealand. *Proceedings of the New Zealand Grassland Association* **50**: 175-179.

RYLE, G.J.A.; POWNELL, C.E.; ARNOTT, R.A. 1981. The influence of N fixation and growth in white clover. *In*: Plant Physiology and Herbage Production. C.E. Wright (eds). Occasional Symposium No. 13. Plant Physiology and Herbage Production, British Grassland society, Hurley, pp 41-45.

SCOTT, D.; KEOGHAN, J.M.; COSSENS, G.C.; MAUNSELL, L.A.; FLOATE, M.J.S.; WILLS, B.J.; DOUGLAS, G. 1985. Limitations to pasture production and choice of species. *In* Using Herbage Cultivars. R.E. Burges and J.L. Brock (ed). Gralands Research and Practice Series No.3, New Zealand Grassland Association Inc. Palmerston North; 9-16.

SHEAFFER, C.C.; LACEFIELD, G.D.; MARBLE, V.L. 1988. Cutting schedules and stands. P. 411-437. *In* A.A.A Hanson, *et al.* (ed)., Alfalfa and alfalfa improvement. Agronomy. Monogronomy. 29. ASA. CSSA. and SSA. Madison, WI.

SHEAFFER, C.C.; MARTEN, G.C. 1991. Kura clover forage yield, forage quality, and stand dynamics. *Canadian Journal of Plant Science* **71**: 1169-1172.

SHEAFFER, C.C.; MARTEN, G.C.; JORDAN, R.M.; RISTAU, E.A. 1992. Forage potential of Kura clover and Birdsfoot Trefoil when grazed by sheep. *Agronomy Journal* **84**: 176-180.

SMETHAM, M.L 1990. Pasture management. *In* Pastures their ecology and management. R.H.M. Langer (ed). Oxford University Press, Auckland: 197-240.

SPEER, G.S.; ALLINSON, D.W. 1985. Kura *Clover (Trifolium ambiguum)*: Legumes for Forage and Soil Conservation. *Economic Botany* **39**: 165-176.

SPENSER, N.; HELY, F.W.; GOVAARS, A.G.; ZORIN, M.; HAMILTON, L.J. 1975. Adaptability of *Trifolium ambiguum* to a Victorian montane environment. *Journal of the Australian Institute of Agricultural Science* **41**: 268-270.

SPENSER, K.; GOVAARS, A.G.; HELY, R.W. 1980. Early phosphate nutrition of eight forms of two clover species, *Trifolium ambiguum* and *T.repens*. *New Zealand Journal of Agricultural Research* **23**: 457-475.

STEWART, A.V. 1979. "Genotypic evaluation of *Trifolium ambiguum*" .Unpubl. M Agr Sci thesis, Lincoln College, New Zealand.

STEWART, A.V.; DALY, G.T. 1980. Growth of an established stand of *Trifolium ambiguum* in a fertile lowland environment. *New Zealand Journal of Experimental Agriculture* **8:** 255-257.

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.

SUCKLING, F.E.T. 1960. Productivity of pasture species on hill country. *New Zealand Journal of Agricultural Research* **3**: 579-591.

TAYLOR, N.L. 1991. Registration of Ky M2 zigzag germplasm. *Crop Science* **31**: 1395-1396.

TAYLOR, N.L., 1995. Characterisation of the United States germplasm collection of zigzag clover (*Trifolium medium* L.) *Genetic Resources and Crop Evolution* **42**; 43-47.

TAYLOR, N.L.; CORNELIUS, P.L.; SIGAFUS, R.E. 1982. Registration of Ky M-1 zigzag clover germplasm. *Crop Science* **22**: 1278-1279.

TOWNSEND, C.E. 1967. Self and cross-incompatibility and general seed setting studies with zigzag clover *Trifolium medium* . *Crop Science* **7** : 76-78

TOWNSEND, C.E. 1970. Phenotypic diversity for agronomic characters and frequency of self-compatible plants in *Trifolium ambiguum. Canadian Journal of Plant Science* **50**: 331-338.

TOWNSEND, C.E. 1971. Registration of C-1 zigzag clover germplasm (Reg. No. GP1). *Crop Science* **11**: 139.

TOWNSEND, C.E. 1985. Miscellaneous perennial clovers. In *Clover Science and Technology*, Taylor,N.L.(ed.). Agronomy Series 25. American Society of Agronomy, Madison, Wisconsin.

TOWNSEND, C.E.; DOTZENDO, A.D.; STORER, K.R.; EDILIN, F.E. 1968. Response of zigzag clover genotypes to management practices. *Canadian Journal of Plant Science* **48**:273-279.

TURKINGTON, R.; BURDON, J.J. 1983. The biology of Canadian weeds 57: *Trifolium repens. Canadian Journal of Plant Science* **63**: 243-266.

WIDDUP, K.H.; TURNER, J.D. 1983. Performance of 4 white clover populations in monoculture and with ryegrass under grazing. *New Zealand Journal of Experimental Agriculture* **11**: 27-31.

WILLIAMS, W.M. 1987a. White clover variability and potential for exploitation. *National White Clover Improvement Programme, Proceedings of a Specialist Workshop* 18-19 August, Armidale, New South Wales, Australia.

WILLIAMS, W.M. 1987b. White clover taxonomy and biosystematics. In White Clover. M.J. Barker and W.M. Williams (ed.), CAB International, Cambridge News LTD, Aberystwth, UK.

WOODMAN, R.F.; KEOGHAN, J.M.; ALLAN, B.E. 1994. Pasture species for drought-prone lower slopes in the South Island high country. *Proceedings of the New Zealand Grassland Association* **54**: 115-120.

ZALESKI, A. 1970. White clover in seed production. In: White clover research. J. Lowe (ed.), Occasional Symposium No. 6, British Grassland Society, pp 165-170.

ZORIN, M.; BROCKWELL, J.; MULLER, W.J. 1976. The use of symbiotic characteristics of nodulated seedlings in tube culture for selection for continuing symbiotic vigour in *trifolium ambiguum* Bieb. *Australian Journal of Experimental Agriculture and Animal Husbandry* **16**: 854-862.

Appendix .1.

Description of the morphological characteristics of the clovers examined within the study used to identify the clover.

Caucasian clover (*Trifolium ambiguum*)

Leaflets are oval, hairless, usually less than 1.5 times as long as broad. Leaflet margins distinctly serrated in lower half only. Stipule extended in a long, tapering point. Free part of stipule at least half the length of leaflets, often longer. Stems do not root at the nodes and roots have rhizomes. Flowers are white, distinctly stalked, and measuring at least 1 cm in diameter. Calyces in mature fruiting heads are neither hairy nor swollen.

Cultivars:

Alpine: The cultivar is a diploid. The leaflets of 65% of plants have a pale green crescent, which has an apex in the centre of the leaflet and arms extending to the margins at points approximately one-third of the distance from the base of the leaflet. The Alpine cultivar is capable of producing more daughter plants from rhizomes than other diploid lines (Oram, 1990).

Monaro: Monaro has a more erect growth habit than the diploid Alpine. The leaflets are petiolate, ovate, strongly veined with numerous fine marginal teeth which are larger at the base of the leaflet. All plants have a centrally located pale-green V-shaped leaf mark. Petioles are green and smooth, sometimes slightly red. Stipules are semi-transparent, green to red and veined (Oram, 1990).

Zigzag clover (*Trifolium medium*)Leaflets hairy on margins and lower surface. Free part of stipule long, narrow and hairy. Stems have a zigzag appearance. Leaflets are usually oval to obovate to diamond shaped and are densely hairy (Leaflets are usually wider than 5mm). Stems do not root at the nodes. Flower heads are stalked. There are no cultivars available of this species. The germplasms looked at were Kentucky and Porters Pass. Kentucky has larger leaves, lighter green in colour and more hairy than the Porters Pass leaves. Porters Pass leaves were less than 15mm wide and were dark green in appearance.

White Clover (*Trifolium repens*)

A perennial herb of postrate habit with hairless stems radiating from a central crown and rooting at the nodes. Leaflets elliptical to broadly ovate or obovate to almost heart-shaped , margin denticulate; veins widely spaced and not much branched, glabrous; leaflet markings usually a white or light green crescent of inverted V on upper surface. Stipules membranous and transparent, completely clasping at base of petiole, glabrous, free portion triangular, pointed, not toothed. There are no practical differences in morphological characters between varieties of white clover other than differences in size of the plants and their individual parts (Oram, 1990).

APPENDIX III

Experimental Design For The Grazing Trial

.1.	(SSH) A M K P	(SSH) P M A K	(SSH) P M A K
.2.	(RGL) A M K P	(RGL) P M A K	(RGL) P M A K
.3.	(SSL) A M K P	(SSL) P M A K	(SSL) P M A
.4.	(RGH) A M K P	(RGH) P M A K	(RGH) P M A K
.5.	(SSH) A M K P	(SSH) P M A K	(SSH) P M A K
.6.	(RGL) A M K P	(RGL) P M A K	(RGL) P M A K
.7.	(RGH) A M K P	(RGH) P M A K	(RGH) P M A
.8.	(SSL) A M K P	(SSL) P M A K	(SSL) P M A K

Note:
* Double lines are fenced areas.
* Within dashed lines area are reps of sub-plots.
* Each species listed are a subplot sown in four rows.
* Thick line shows gate way end.

Key:
* Main plots = Grazing Treatments

* Plots 1 and 4
SSH = Set Stocked Hard

* Plots 3 and 8
SSL = Set Stocked Lax

* Plots 4 and 5
RGH = Rotational Grazed Hard

* Plots 2 and 6
RGL = Rotational Grazed Lax

Subplot Species
Porters Pass
K = Kentucky
A = Alpine
M = Monaro

Appendix III

Visual score of rhizomatous clover and white clover cover on the 15th of February 1995 before the trial commenced. The assessment was after a dry summer and after grazing had ceased in December 1994.

Treatment	Clover Type	Visual Score
Set Stocked Hard	Alpine	1.5
	Monaro	2.3
	Kentucky	0.5
	Porters Pass	0.5
	White Clover	1.5
Set Stocked Lax	Alpine	1.5
	Monaro	2.0
	Kentucky	0.5
	Porters Pass	1.0
	White Clover	2.0
Rotational Grazed Hard	Alpine	1.0
	Monaro	2.5
	Kentucky	0.5
	Porters Pass	0.5
	White Clover	1.5
Rotational Grazed Lax	Alpine	2.0
	Monaro	3.0
	Kentucky	1.0
	Porters Pass	1.0
	White Clover	2.5

Key to visual scoring; 0 = 0-1% cover of clover

1 = 1 - 5% cover of clover

2 = 5-10% cover of clover

3 = 10-20% cover of clover

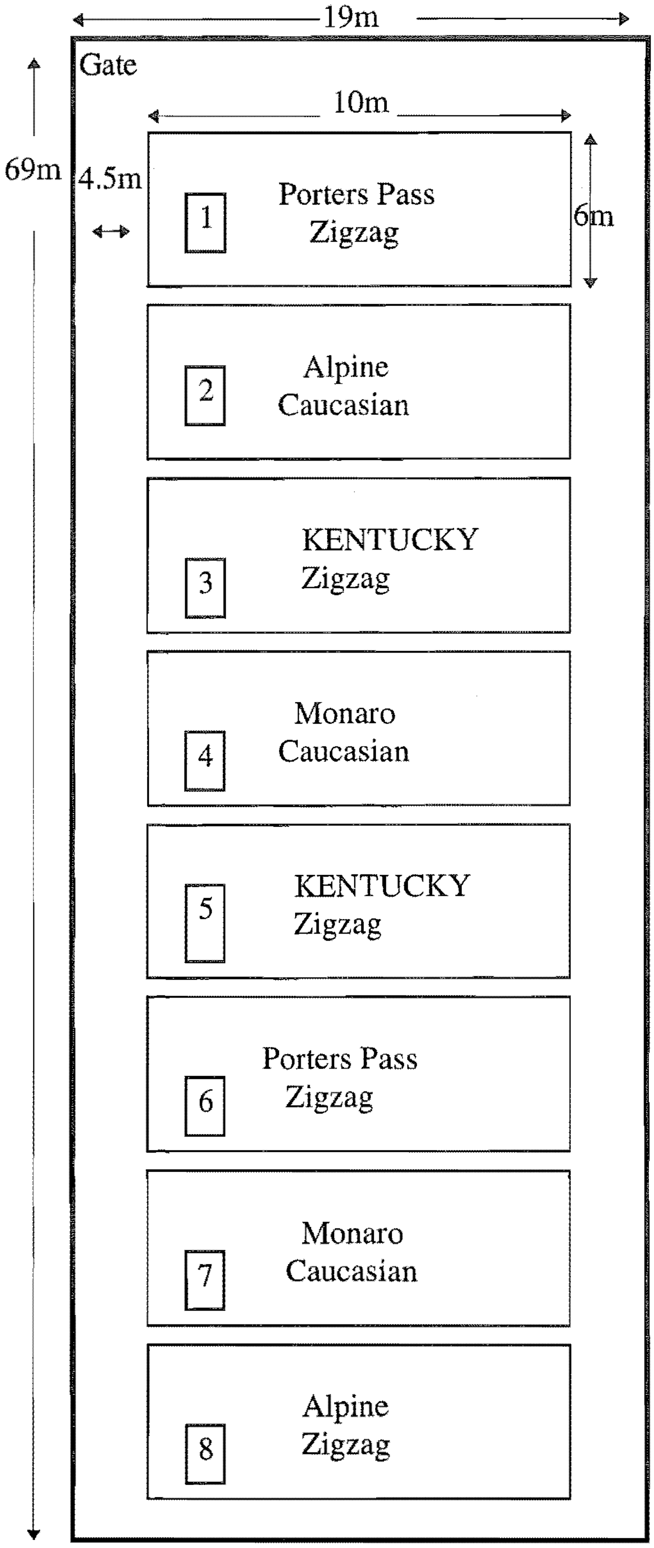
4 = 20-50% cover of clover

5 = 50-100% cover of clover

Clovers within set stocked pastures in both hard and lax treatments scored poorly with cover between 0 to 10%. In rotational grazed pastures percentage cover of Monaro and white clover was particularly good 10 to 30%. The other three clovers assessed scored poorly.

Appendix IV

Supplementary Trial Experimental Plots



Key: Dark line indicates fence line

Note:

* Distance between seed plots is 1.5m
* From the boundary fence to three metres in is sown ryegrass.
* Each plot had 95 seedlings originally sown into them. Seedlings were sown in five rows one metre apart.