ESTABLISHMENT AND GRAZING MANAGEMENT OF 'GRASSLANDS PUNA' CHICORY (*Cichorium intybus* L.)

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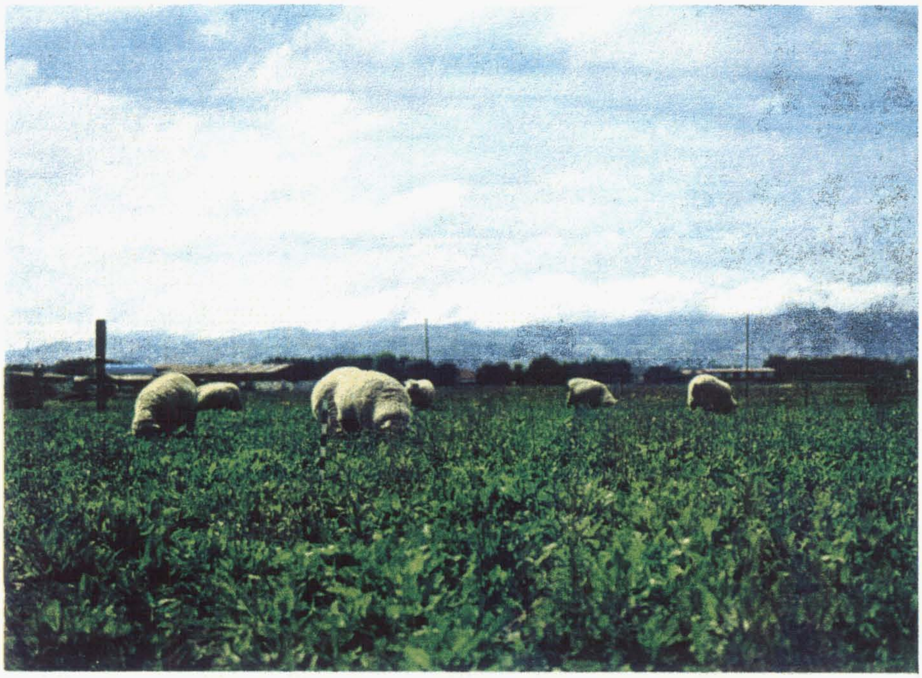

(a) Vegetative stage

(b) Reproductive stage

Chicory (*Cichorium intybus* L

Abstract of a thesis submitted in partial fulfilment of the requirements for the Degree of M.Agr.Sc.

ESTABLISHMENT AND GRAZING MANAGEMENT OF 'GRASSLANDS PUNA' CHICORY (*Cichorium intybus* L.)

by Javier Arias-Carbajal

'Grasslands Puna' chicory was bred for dryland farming. Chicory is a pasture herb which is dormant during winter but actively grows in spring, summer and autumn. A wide range of sowing rates have been reported for pure and mixed stands but establishment recommendations have not been clearly defined. Chicory will not survive frequent grazing. Reported results indicate that chicory should be grazed with a long spelling time and lax defoliation, but recent work has shown that hard grazing in spring is required to control primary stem growth so that maximum leaf production can be achieved.

Three experiments were carried out to find out more about establishment and grazing management of chicory. The objectives were (a) to determine a suitable chicory sowing rate for either pure swards or pasture mixtures with clovers or winter active grasses and (b) to investigate the responses of chicory to two grazing frequencies and two grazing intensities combined in a 2^2 factorial design to give four grazing treatments.

Herbage mass, botanical components, plant population and taproot weights were measured in two chicory sowing rate field experiments. Plots measured 1.5 m and 2.5 m (3.75 m^2). Companion species were 'Grasslands Kopu' white clover, 'Grasslands Pawera' red clover, 'Grasslands Matua' prairie grass and Grasslands Maru' phalaris. In experiment A there were 27 treatments of 8 single species stands (4 pure chicory sowing rates - 0.75, 1.5, 3 or 6 kg/ha - and each companion species), 10 binary mixtures, and 8 complex mixtures. In experiment B treatments were binary mixtures of the four chicory sowing rates and prairie grass or phalaris. Sampling dates for the first three characteristics were 24-28 February, 15-20 May, 16-17 August, and 15-19 November 1993. Taproots were dug out only from pure chicory plots on 16 December

1993.

Pure chicory production was greatest at high sowing rates. From four harvests, total yields from chicory sown alone ranged from 920 g DM m^{-2} yr^{-1} at 0.75 kg seed/ha to 1480 g DM m^{-2} yr^{-1} at 3 kg/ha. When mixed with 'Pawera', which yielded from 140 to 380 g DM m^{-2} yr^{-1}, chicory yielded from 780 to 1270 g DM m^{-2} yr^{-1}. Chicory yielded 830 to 1280 g DM m^{-2} when mixed with 'Kopu' (45 to 250 g DM m^{-2} yr^{-1}). In general dry matter yields of companion species and weeds decreased as chicory populations increased. The large seeded species, 'Matua' prairie grass and 'Pawera' red clover, were more competitive with chicory than the slower establishing small seeded species, 'Maru' phalaris and 'Kopu' white clover. Final population after one year increased from 50 plants m^{-2} at 0.75 kg/ha to 135 plants m^{-2} at 6 kg/ha. Individual taproots weighed four times more at 0.75 kg than at 6 kg/ha. Taproot yield was 350 g DM m^{-2} at low sowing rates and 270 and 260 g DM m^{-2} at 3 and 6 kg/ha, respectively. Mean crown diameter declined from 26 mm at 0.75 down to 18 mm at 6 kg/ha.

In the grazing trial the four grazing treatments were replicated five times. Grazing plots were 480 or 890 m^2. Replicates of the grazing treatments were sequentially grazed by ewe hoggets (35-50 kg live weight). There were ten grazing cycles starting from 25 January 1993 and finishing in February 26 1994. Pre- and post- herbage mass, plant components and plant population were measured. Taproot and crown measurements were recorded in March and July 1993 and March 1994. Volunteer white clover appeared in early spring and it was also measured.

The hard grazing treatments produced more high quality feed (leaf) than the lax grazing treatments. Total pre-grazing dry matter yields of chicory were 1620, 2840, 2080 and 3045 g DM m^{-2} $year^{-1}$ under hard frequent (HF), lax frequent (LF), hard infrequent (HI), and lax infrequent (LI), respectively. From the latter leaf yields represented 90 and 37% in the HF and LI treatments, respectively. In March 1994 taproots weighed less under hard or frequent grazing than under lax or infrequent grazing. Mean crown diameter was significantly greater (18.9 mm, $P< 0.000$) under infrequent than under frequent grazing (15.9 mm). Chicory crown diameter was also smaller under hard grazing (16.5 mm, $P<0.003$) than lax grazing (18.2 mm). Number of crown buds per taproot varied ($P< 0.044$) from 2.5 to 2.2 under frequent and

infrequent grazing, respectively. When chicory was heavily grazed crown buds numbered 3.2 but reduced to 1.5 under lax grazing. Volunteer white clover was most productive in the laxly grazed plots and appeared to reduce chicory population and yields. *Sclerotinia spp* fungus also appeared to cause more chicory plant death in laxly grazed plots.

It was concluded that pure chicory should be sown in a range of 1.5-3 kg seed/ha. Chicory sowing rates lower than 1.5 kg/ha are recommended for binary or complex mixture with clovers or winter active grasses. Some grazing strategies are discussed regarding chicory as a versatile pasture herb which can tolerate different grazing managements so long as the plant is spelled between grazings. Hard grazing in spring is recommended to control primary reproductive stems. Longer spelling in autumn may be important for maintenance of taproot reserves.

Keywords : *Bromus wildenowii* Kunth., clovers, crown diameter, crown bud number, cutting, 'Grasslands Puna' chicory, *Cichorium intybus* L., grazing management, herbage mass, *Phalaris aquatica* L., plant competition, plant components, plant population, *Sclerotinia spp.*, sheep grazing, sowing rates, *Trifolium pratense* L., *Trifolium repens* L., taproot weight, volunteer clover, winter grasses.

Con todo mi amor a mi esposa Flavia V. e hijos Mónica S. Eliana K. y Javier F., quienes soportaron mis largas horas de ausencia, toleraron con entereza el largo camino y me dieron las fuerzas para terminar.

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CHAPTER 1

INTRODUCTION

New Zealand pastoral farming productivity depends mainly on rainfall distribution and temperature pattern. The eastern coast of both islands have drought-prone areas where rainfall is less than 800 mm. That rainfall may be unreliable in some years and in winter cold areas pasture production is also reduced by low temperatures. The dry periods may occur any time from late spring to autumn and pasture yield is greatly reduced. Animal production systems have been adapted to fit in with pasture supply patterns, but these systems do not easily accommodate extreme conditions.

In dryland farming the most common established pasture is a mixture of perennial pasture species such as perennial ryegrass (*Lolium multiflorum* L.) and white clover (*Trifolium repens* L.). Perennial ryegrass has been used for a very long time, but it has shown susceptibility to some pests such as grass grub (*Costelytra zealandica*), Argentine Stem Weevil (*Listronotus bonaerensis*) and porina caterpillar (*Wesenia* sp) especially during drought conditions. Ryegrasses infected with the endophyte *Acremonium lolii* have also been identified as causing ryegrass staggers, a neural-disorder of sheep which is caused by the production of the alkaloid lolitrem B, in the leaf sheaths of the grass tillers.

As a result of these weaknesses of ryegrass New Zealand farmers have been looking for good alternative perennial grass species. For instance, some grasses such as tall fescue (*Festuca arundinacea*), cocksfoot (*Dactylis glomerata*), prairie grass (*Bromus wildenowii*) and phalaris (*Phalaris aquatica*) have been thought of as complementary species to cover winter, early spring or summer pasture production gaps. All those species show tolerance to the pests and diseases of ryegrasses but they also have some agronomic limitations such as slow establishment or poor persistence under hard grazing.

Pasture herbs such as 'Grasslands Puna' chicory (*Cichorium intybus* L.) have also been improved to fill the restricted options for high quality summer pasture production (Rumball, 1986). The taprooted herb, chicory has been shown to be an excellent feed supplier because it produces dense leaf during the high temperature seasons (summer-autumn). Also its tolerance to drought conditions and higher yields than traditional pastures has resulted in chicory being adopted as a valuable summer greenfeed for New Zealand dryland farming. Chicory is also appreciated because it is not affected by any of the main pasture pests or diseases. The only disease which affects chicory is *Sclerotinia* - a root-crown disease that can reduce chicory populations very rapidly.

Agronomic information of chicory is not conclusive especially regarding grazing management and recommended sowing rate in pure stands or in mixtures. Individual studies indicated sowing rates from 1 to 7 kg/ha for pure stands or sown with white clover and from 0.5 to 10 kg/ha when sown in pasture mixtures. Chicory is not tolerant to intensive and frequent grazing (Rumball, 1986). Also chicory was found to be low producing when it was cut at ground level (Clark *et al.*, 1990a) or when it was heavily grazed (Matthews *et al.*, 1990). However it has not been shown conclusively, whether or not chicory needs residual leaf for rapid regrowth after grazing and if repeated hard grazing will adversely affect persistence.

Given this background two field plot experiments were established to determine chicory sowing rates in pure stands or in mixtures and a grazing experiment was carried out to investigate the response of pure chicory swards to defoliation by sheep. The sowing rate field experiments were designed to study four chicory sowing rates in pure stands or in various mixtures using two clovers and two winter active grasses. They were evaluated from November 1992 to December 1993. In a third experiment grazing treatments were combined in a 2^2 factorial design with five replicates. Two grazing frequencies (short and long spells) and two intensities (lax or hard grazing) were compared on 1.2 ha of chicory in ten grazing cycles from January 1993 to March 1994.

CHAPTER 2

CHICORY AGRONOMY

2.1 INTRODUCTION

'Grasslands Puna' chicory is of importance as a high quality spring summer-autumn fodder in New Zealand. Its importance arises from the high animal growth rates which can be achieved, 290 g/head/day for sheep and 900 g/head/d for steers (Fraser *et al.* 1988). However, there have been few published results on the use of chicory as a pasture herb since it was released in 1986 (Rumball, 1986).

This review concentrates on the limited literature available on 'Grasslands Puna' chicory (*Cichorium intybus* L.) performance as a pasture herb in both New Zealand and overseas. The chapter also includes a description of the origin and taxonomy of chicory and its agronomic characteristics both above and below ground. The sociability of chicory with companion species and grazing requirements under different animal production systems are also discussed. Additionally, some information on root chicory (*Cichorium intybus* var. *sativum*) has been used, when necessary, to support specific points such as taproot characteristics (Knobloch, 1954; Frese *et al.*, 1991).

2.2 TAXONOMY AND ORIGIN

Chicory (*Cichorium intybus* L.) is a perennial herb which belongs to the genus *Cichorium*, tribe *Lactuceae*, subfamily *Cichorioideae*, family *Asteraceae* (ex-*Compositae*) (Garnock-Jones, P.J., 1987; Schoofs and Langhe, 1988). Chicory is native to Europe, Central Asia, North Africa and South America (Hare, 1987) and it is found as a weed in many places of New Zealand (Garnock-Jones, P.J., 1987). Chicory plants can be used for leaf or root production (Frese *et al.*, 1991).

In New Zealand, the only cultivar available, 'Grasslands Puna' Chicory, was selected as a pasture herb from a collection of chicory genotypes at D.S.I.R. Grasslands Division Palmerston North (Rumball, 1986) to supply summer green feed for dryland farming areas.

2.3 CHARACTERISTICS OF CHICORY

2.3.1 Growth of chicory under- and above ground

2.3.1.1 Chicory taproots

There is little information on taproot formation in leaf chicory. In root chicory (*Cichorium intybus var. sativum*) researchers have found that the taproot may have different genetically-controlled forms. Roots may vary from smooth without much branching to strong conical shapes (Frese and Dambroth, 1987). The importance of the taproots was reinforced by Sechley (1990) who found that, as a perennial weed, the chicory taproot stores carbohydrates, nitrate, aminoacids and protein pools. Frese *et al.* (1991) found that, in root chicory, the dry matter content of taproots was positively correlated with the total sugar content (Table 2.1); they also showed that there was little genetic variation in the total sugar/dry matter content ratio.

TABLE 2.1 Root yield, dry matter percent and total sugar content of root chicory taproots

Root chicory taproots	Root yield (kg/m^2)	% DM	Total sugar content (%)
Minimum	4.3	22.2	17.4
Average	5.4	24.6	20.0
Maximum	6.3	26.8	21.9
Significance	*	*	*

Remark: Plant population: 18 plants/m^2

Source : Frese *et al.* (1991)

Taproots are important in plant survival and longevity, particularly in winter cold areas where growth is very limited for several months of the year. A knowledge of the growth and development of taproots should make it possible to identify a decline in vigour of chicory plants.

2.3.1.2 Vegetative and reproductive growth of chicory

Chicory grows vegetatively during its first year after establishment (Rumball, 1986). Chicory produces new growth from a basal rosette which is formed at an early stage in its establishment (Knobloch, 1954). It produces flowering stems in spring after vernalization during winter (Hare, 1987). Thus, chicory develops flowers during the long days and warm temperatures of mid-spring and summer. Its maximum flowering, which has been recorded at 150 flowers/m^2, generally occurs during mid summer (Hare *et al.* 1987).

The centre of the main flowering stem of chicory is hollow with a maximum diameter at ground level. Chicory develops reproductive stems from late October (Hare, 1987; Hare *et al.*, 1987). Clark *et al.* (1990b) showed that the largest dry matter yield was in the 0-20 cm stem height stratum. They also reported that a chicory sward, ungrazed since early spring, produced more than 60% of its total DM in stems. Also, leaf production was about 30% and flowerhead 4% when measured in November (Table 2.2).

TABLE 2.2 Means for chicory live component dry matter pooled for three sampling periods for pre-grazing (from 9 Nov to 18 Dec. 1987)

Component	Lax	%	Hard	%
Leaves	1500	29.2	1400	33.6
Stems	3400	66.3	2600	62.5
Flowerhead	230	4.5	160	3.9
Total	5130	100.0	4160	100.0

Adapted from Clark *et al.* (1990b)

2.3.2 Susceptibility to pest and disease

There is no published data on chicory damage by common pasture pests such as grass grubs (*Costelytra zealandica*) and Argentine stem weevil (*Listronotus bonaerensis*) (Rumball, 1986; Hare *et al*, 1987). However, Hare *et al.* (1990) mentioned that aphids (*Acyrthosiphon spp.*) and tomato fruit worms (*Heliothis armigera*) can infest chicory seed crops during the flowering stage. Grass grubs feed on chicory roots but do not appear to cause major damage (personal observation).

Sclerotinia sclerotiorum., root fungal pathogen, causes the most common disease in chicory (Hare *et al.*, 1990). It can drastically reduce a chicory population, particularly in areas with high soil moisture content (Hawthorne and Jarvis, 1973; Hawthorne, 1973; Willetts and Wong, 1980). Apothecia of *Sclerotinia* are likely to appear in significant numbers from September to early November when conditions are cool (10-15ºC) and moist (Hawthorne, 1973). *Sclerotinia* usually lives in the soil and litter (Hawthorne, 1973; Willetts and Wong, 1980) and so it may easily spread under rotational grazing. Captan (dichlofluanid or thiram), fungicide control has been successfully (Hawthorne, 1973) but cost is prohibitive under grazing conditions.

The host range of *Sclerotinia species* is very wide and includes forage legumes (Willetts and Wong, 1980). Ledgard *et al.* (1990) indicated that 'Pawera' red clover deteriorated in the second year of establishment due to the effect of clover rot (*Sclerotinia trifoliorum*). They also noted that moderate hard grazing in summer worsened the effect of the outbreak. Chicory is not susceptible to *Sclerotinia* ~~*sclerotiorum*~~ (Bourdot, 1994).
trifoliorum.

2.3.3 Nutritive value

Chicory digestibility varies according to the part of plant under consideration. Clark *et al.* (1990) reported flowers had 81% *in vitro* dry matter digestibility (IVDMD) and these were more digestible than live leaf (77%) and main stem (46%). Nitrogen content in those parts was positively correlated to digestibility (2.6, 1.5 and 0.24% of N in flowers, live leaf and main stem, respectively).

Chemical composition of Puna chicory has been cited by Crush and Evans (1990) in New Zealand and Jones (1990) in England (Table 2.3). Crush and Evans (1990) reported chemical composition of chicory grown at nine different sites from North and South Island. They found that concentrations of major elements were similar in chicory grown under field or glasshouse conditions, except phosphorus which was always higher under glasshouse. However, it is likely that some differences in pH, nutrient status and organic matter content of soils could have an influence in the values for field grown plants. Reported data by Jones (1990) are generally within the same range as those given by Crush and Evans (1990). However, Jones collected chicory samples from a field previously cropped with forage peas and fertilized with 120 kg N/ha/year plus farmyard manure (14, 33, 33 kg/ha of N, P_2O_5 and K_2O, respectively).

TABLE 2.3 Chemical composition of 'Grasslands Puna' chicory reported in New Zealand (Crush and Evans, 1990) and England (Jones, 1990)

Nutrient	Crush and Evans (1990)	Jones (1990)	
		12/6/89	30/8/89
Nitrogen (%)	2.15-3.90	2.0	2.7
Phosphorus (%)	0.24-0.52	0.36	0.37
Potassium (%)	4.5-9.2	4.6	5.3
Calcium (%)	1.04-1.64	1.2	1.5
Magnesium (%)	0.20-0.39	0.2	0.2
Sodium (%)	0.19-0.66	0.25	0.1
Zinc (ppm)	31-385	66	75
Manganese (ppm)	(404)	57	55

2.3.4 Importance of chicory in animal performance

The main use of chicory is to achieve fast animal growth rates. At Lincoln, Fraser *et al.* (1988) showed that 6-week old Dorset x Coopworth ram lambs gained 290 g/head/day in spring. When they used 9-week Coopworth ram lambs their daily live weight gain (DLWG) was 168 and 238 g at low (1.5 kg DM/head/day) and high (3 kg/hd/d) allowance, respectively. Komolong *et al.* (1992) reported DLWG of 180 to 365 g/day from 10-week Border Leicester ram lambs. In their experiment the highest peak of LWG was in mid December. In southwest Australia, Spiker *et al.* (1992) reported DLWG over 100 g/day in finishing lambs (Dorset and white Suffolk x Border Leicester Merino cryptorchids).

These results are not directly comparable as different animals were used in the experiments. Also, the DLWG reported in New Zealand was obtained from irrigated chicory swards which contrast with the dryland research in southwest Australia. However, chicory is emphasised as a potential supplier of fodder for finishing lambs in dry farming areas.

2.4 AGRONOMIC REQUIREMENTS

2.4.1 Sowing date

'Grasslands Puna' chicory should be sown during spring-early summer (Rumball, 1986; Hare *et al.*, 1987). In Canterbury, mid-summer sowing of chicory is generally unsuccessful, unless irrigation is available, because of dry soil conditions. Late summer sowings (mid February), are also likely to be unsuccessful as chicory plants have only a small taproot by winter. Therefore, they are more susceptible to weed competition and frost or drought conditions than larger plants (Rumball, 1986). Sowing after March is not recommended at all because chicory seedlings develop small taproots during the lower soil temperatures of winter (Hare *et al.*, 1987) and the plants are very susceptible to winter active weeds.

2.4.2 Seeding rate

There are no published results from specific experiments studying sowing rates for chicory in pure or mixed swards for grazing. Opinions vary about which rate is appropriate for good establishment. For establishing a pure chicory sward the lowest recommended sowing rate, 1 kg seed/ha, has been reported by MacFarlane (1990); 2 kg seed/ha was recommended by Rumball (1986) and Hare *et al.* (1987). Higher sowing rates such as 5 and 7 kg seed/ha have been used by Linton *et al.* (1991) and Sevilla (1989).

In mixed pastures the highest rate is reported by Fraser *et al.* (1988) who used 10 kg in binary mixtures with ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea*), cocksfoot (*Dactylis glomerata* L.), phalaris (*Phalaris aquatica* L.), or prairie grass (*Bromus wildenowii* Kunth). MacFarlane (1990) recommended 3 kg chicory seed/ha when mixed with 3 kg/ha 'Pawera' red clover (*Trifolium pratense* L.); 3 kg/ha 'Pitau' white clover (*T. repens* L.) and 10 kg/ha 'Matua' prairie grass or 5-6 kg/ha 'Kahu' timothy (*Phleum pratensis*). In Argentina, Maddaloni *et al.* (1985) found that the beef stocking rate could be increased by sowing pastures using 5 kg/ha chicory cv 'San Pedro' and 1 kg/ha white clover cv 'El lucero'.

The adjustment of seeding rate must be done according to the number of plant components in a mixture or as in a pure sward a prediction of the number of volunteer plants that may appear after sowing. For instance most broad leaf weeds can compete with chicory after sowing (Hare *et al.*, 1987). Docks (*Rumex spp*), thistles (*Carduus nutans*, *Cirsium arvense*, *Cirsium vulgare* or *Cardus tenuiflorus*), and dandelion (*Taraxacum officinale*) are common weeds in most farming areas (Healy, 1982). Chicory germinates rapidly and competes successfully if soil conditions are warm and moist (Lancashire and Brock, 1983).

From the preceding paragraphs it is apparent that there are no firm recommendations for chicory seeding rate for either pure or mixed chicory swards. At low seeding rates chicory may be dominated by companion species or volunteer plants resulting in a decline in population. Kise *et al.* (1987) also considered that chicory does not cover the ground efficiently and, therefore, it losses high amount of water by evapotranspiration as well as evaporation from soil. In contrast, at high seeding rates chicory may compete strongly with companion species and reduce weed populations. However, seedlings at low chicory density generally become larger and more vigorous than those seedlings at high populations.

2.4.3 Soil fertility requirements

Chicory is insensitive to soil pH (Crush and Evans, 1990) and grows well under different soil fertility regimes (Hare *et al.*, 1987).

Chicory may respond to nitrogen fertilization depending on site conditions and stand age (Romero *et al.*, 1988; Clark *et al.*, 1990a). Clark *et al.* (1990a) found, in the Manawatu, that a two-year old chicory sward produced 30 and 87 % more dry matter using 50 or 200 kg N/ha, respectively, compared with 0 kg N/ha (Table 2.4). They considered the best rate was either 0 or 50 kg N/ha because these were the only treatments where regrowth DM was not drastically reduced. They found that plant density was not affected at 0 and 50 kg N/ha (20.8 ± 1.8 and 21 ± 2.3 plants/m^2, respectively) compared with 200 kg N/ha (10.4 ± 1.2 plants/m^2).

TABLE 2.4 Effect of nitrogen level on total DM, leaf DM and regrowth DM yields of chicory. Aorangi Research Station, Manawatu (26/10/1988 to 7/2/1989).

N level (kg/ha)	Total DM (kg/ha)	Leaf DM (kg/ha)	Regrowth DM[a] (kg/ha)
0	3030	1690	1720
50	3900	2190	1670
200	5680	2601	1230
$LSD_{0.05}$	479	393	235
Significance	***	***	**

a/ Period 10 January - 7 February 1989.
Soil type : Kairanga sandy loam.
Source : Clark *et al.* (1990a)

The response of chicory to low N application may become a controversial issue. In Argentina, Romero *et al.* (1988), after a 3-year experiment, showed that chicory responded well to low levels of N fertilization in spring; however, the effect was only in the first cutting. They found that the average N response was from 4.5 to 6.2 kg DM/kg N by applying less than 150 kg N fertiliser. The response to N per kg N decreased to zero at 350 kg N/ha where yield maximum was reached. Estimated amount from the data of Clark *et al.* (1990) showed that 8 kg DM of chicory were produced per kg N applied at 50 kg N/ha. These N responses to chicory are less than is normally expected from grasses; similar low responses per kg N fertiliser have been observed at Lincoln University (Lucas, 1994).

Variations in reported data rise from differences in soil and climate conditions. However, it is possible that chicory response to N fertilizer may be inversely related to the balance of nutrients and reserves stored within its taproot.

2.4.4 Irrigation

Chicory may require an initial watering in the seedling stage during high temperatures and in advanced stages of development before flower production (Hare *et al.*, 1990). Chicory grows successfully in areas with variable rainfall because it may reach water in deep soil horizons with its long tap-root.

2.5 SOCIABILITY OF CHICORY

There are few published studies of sociability of chicory with other species so it has not been possible to identify what temperate pasture plants are compatible with it. Chicory has a marked seasonal production with highest yields occurring during the summer-autumn period (Rumball, 1986; Sevilla, 1989). There is little growth between May and August in the South Island of New Zealand so it needs complementary species to cover this gap.

2.5.1 Potential companion legumes

Legumes in mixtures with chicory have not been extensively reported in New Zealand. In Argentina, Romero et al. (1989) reported that red clover cv 'Quinequelli' was a good companion legume for chicory (cv 'Rafaela') and that chicory contributed in a range of 50 to 70 percent to the total dry matter. In that mixture chicory yielded about 12000 and 15500 kg DM/ha in first and second year, respectively. However, red clover did not persist after the second year. This may have been partially due to infrequent defoliation.

Red clover (*Trifolium pratense* L.) is a deep/tap rooted herbaceous legume so it can better resist drought conditions (Langer, 1992). 'Grasslands Pawera' red clover is a perennial tetraploid legume with late flowering and high dry matter yields (Anderson, 1973). Its main advantage is its overwintering ability which it has been related to greater accumulation of total carbohydrate reserves.

There is no reference referring to binary mixtures of chicory and white clover. White clover (*Trifolium repens* L.) is the most important legume for temperate pastures, and in New Zealand, it has been the basis of pastoral farming for a very long time (Langer, 1992). White clover has prostrate stolons which rooted easily into the ground and spread forming a dense cover of leaves. 'Grasslands Kopu' white clover is one the latest bred cultivars for intensively grazed cattle pastures, especially dairy farming (Moloney *et al.* 1988, Langer, 1992). 'Kopu' white clover is an erect cultivar with thicker stolons and larger leaves than other cultivars and is resistant to stem nematodes (Bosh *et al.*, 1986). It is likely that the large leafed cultivars of white clover such as 'Kopu' would be appropriate legume companions for chicory. Both require rotational grazing and the larger average petioles of 'Kopu' should be enable it compete with tall summer growth of chicory better than smaller leafed cultivars of white clover. The stoloniferous habit of white clover makes well suited as a chicory companion. Any gaps in the chicory canopy can be exploited by the very plastic growth form of white clover.

2.5.2 Potential companion grasses

Recommendations for winter-active growth grasses such as 'Grasslands Matua' prairie grass (*Bromus willdenowii* Kunth.) and phalaris (*Phalaris aquatica*) have been made by Fraser *et al.* (1988) and MacFarlane (1990). Both prairie grass and chicory are recommended for lax rotational grazing so they could be compatible in grazed pastures. However, chicory does not tolerate grazing during dormancy (Rumball, 1986) and so the grass growth should not be grazed in winter. Instead, the grass could be grazed in early spring during dry conditions to avoid chicory crown damage but before the first flush of chicory spring growth.

However, chicory may dominate in a binary mixture in the long term. Fraser *et al.* (1988) showed that chicory and 'Matua' prairie grass persisted for three years compared to 'Maru' which decreased in yield during the same period (Table 2.5).

TABLE 2.5 Mean growth scores of 'Matua' prairie grass, 'Maru' phalaris and chicory in binary mixtures in Southland. (0=absent, 5=excellent)

	'Matua'	'Maru'	'Puna'
Sowing rate (kg/ha)	60	20	10
Mean growth score :			
Establishment	4.1	3.2	5.0
Year 3	3.2	1.8	4.0

Source : Fraser *et al.* (1988)

'Grasslands Matua' prairie grass is a tall erect grass which was bred as a superior cool season and dry summer condition pasture species by Rumball (1974). This cultivar is a hexaploid (x=6 chromosomes), and is highly palatable at all growth stages, including reproductive. Moreover, it tolerates grass grub and porina and it does not produce ryegrass staggers in livestock as does perennial ryegrass. However, prairie grass has poor persistence and productivity under frequent defoliation on dry or infertile soils. Under wet conditions, prairie grass may be infected by smut head (*Ustilago bullata* Berks) (Falloon, 1976).

'Grasslands Maru' phalaris is a low alkaloid (less than 0.2% of DM) selection which develops a deep root system (Rumball, 1980). Maru persists under frequent grazing but phalaris staggers may appear in stock at some times of the year (Rumball, 1980). Its resistance to grass grub and Argentine stem weevil make it a suitable species for dry areas such as Canterbury (Lancashire, 1984). Indeed its cool season growth in mild, moist winters is its main advantage (Stevens *et al.*, 1989). Another of its advantages is its active and tall growth in spring and autumn (Hume and Lucas, 1987) when chicory is growing. However, this could become strong competition between the two species.

2.5.3 Potential complex mixtures of grass-legume and chicory

There are few reported experiments describing complex mixtures of chicory with grasses and legumes. Further work is needed to understand the response of chicory with increasing numbers of plant species in a sward.

In complex mixtures, the contribution of chicory to total dry matter may be reduced by the increased number of companion species. In Southland, New Zealand, Fraser *et al.* (1988) found that chicory contributed proportionately more to the total DM yield in a part mixture (39.5%) in comparison with a full mixture (32%) (Table 2.6). The full mixture with chicory contained grasses such as 'Nui' ryegrass, 'Wana' cocksfoot, 'Roa' tall fescue, 'Matua' prairie grass, and 'Maru' phalaris; legumes were 'Huia' white clover and 'Pawera' red clover. The part mixture did not contain 'Nui', 'Matua' and 'Pawera'.

TABLE 2.6 Three year mean total yields, the proportionate contribution of 'Puna' chicory to total yield, and density of chicory plants in complex mixtures. Average of two soil types in Southland

Parameter	Full mixture			Part mixture		
	Mar-Oct	Nov-Feb	Annual	Mar-Oct	Nov-Feb	Annual
Yield (kg/ha)	7500	6000	13500	6500	5100	11600
Puna (%)	24.5	41.5	32	33.5	46.5	39.5
Plants per m^2	-	46	43.5	37	28.5	-

Source : Fraser *et al.* (1988)

Some companion species of chicory may show more competitiveness than others. In Argentina, Kise *et al.*, (1987) compared chicory in pure swards (560 plants/m^2) and in mixtures (320 plants/m^2) with grasses (tall fescue, cocksfoot, oats and annual ryegrass; 380, 500, 140, 480 plants/m^2, respectively) and legumes (alfalfa, white clover, red clover, and Persian clover; 490, 330, 140, and 290 plants/m^2, respectively). They concluded, after two years (Table 2.7), that chicory, alfalfa (*Medicago sativa* L.) and cocksfoot constituted the most productive mixture (12400 kg DM/ha), yielding twice as much as pure chicory (6700 kg DM/ha). Pure chicory swards were not considered suitable as lack of ground cover resulted in weed invasion. This has also been noted by Hare *et al.* (1990).

TABLE 2.7 Total dry matter yield (kg/ha) and proportionate contribution (PC) of chicory in mixture

Mixture	Yield (kg DM/ha)	PC of chicory (%)
1. Chicory (CH) alone	6700	100
2. CH + WC + TF	8200	70
3. CH + AA + CF	12400	48
4. CH + RC +TF + IRG	12100	45
5. CH + RC + TF + O	10800	42
6. CH + PC + O	8400	64
7. CH + PC + IRG	8100	62

(Grasses: TF= tall fescue, CF= cocksfoot, O= oat and IRG= annual ryegrass; Legumes: AA= alfalfa, WC= white clover, RC= red clover, and PC= Persian clover)

Source : Kise *et al.* (1987)

Chicory can become dominant even at a low seeding rate. In a Southland experiment, Casey (1992) found that chicory, sown at 1 kg seed/ha, mixed with 'Maru' phalaris (8 kg/ha) and 'Tahora' white clover (3 kg/ha), contributed 42-70 % to the total DM yield of pasture, principally during summer. 'Tahora' DM contribution was in a range of 20-33% through the grazing seasons. 'Maru' DM yield contribution was less than 5 %. Although chicory was sown at a low sowing rate, its distribution in the sward and grazing behaviour of goats permitted its dominant contribution to the pasture.

From these results it would appear that the contribution of chicory in a mixed pasture depends upon the competitive ability of the species with which it is sown at the early establishment stage and subsequently during routine grazing.

2.6 CHICORY GRAZING

The grazing of 'Puna' chicory has been studied more in pure swards rather than in mixtures. This is evident since the increase of number of plant species in a sward will increase the difficulties in studying the response of chicory to grazing. As chicory does not tolerate hard or prolonged grazing it should not be used in pastures required for continuous grazing or short rotations at very high stocking rates (Rumball, 1986; Matthews *et al.*, 1990).

2.6.1 Pure chicory sward

In experimental pure swards, Clark *et al.* (1990b) showed that clipping chicory at intervals of 4 weeks, at either ground level or 10 cm cutting height, maximized dry matter production. In grazed swards, Matthews *et al.* (1990) recommended that chicory should be grazed every 5 weeks. Their reason for this was to increase leaf:shoot ratio and to reduce reproductive stems in later stages.

Although clipping at ground level can increase DM yield, it can also reduce plant population. Clark *et al.* (1990b) found that plant density was reduced by 30 percent when chicory was cut at ground level (14.4 ± 1.4 plants/m^2) in comparison to the 10-cm height cutting (20.8 ± 1.7 plants/m^2). Hard grazing may have the same effect because growing points become damaged, especially by grazing sheep. Chicory has its growing points very close to ground level forming a basal rosette (Knobloch, 1954). Also, it has a pseudo-shoot close to the basal rosette and linked through a fragile petiole (Rumball, 1986) which is easily damaged by stock.

As mentioned earlier, winter grazing of chicory is also not recommended. During the cold period chicory has prostrate leaves and restricted shoot growth (Rumball, 1986; Sevilla, 1989).

2.6.2 Chicory in mixtures

In mixed swards grazing behaviour may seasonally have an effect on dry matter yield of chicory. Casey (1992), in Southland, reported that chicory reduced by 23 or 48% its total DM yields in spring or autumn, respectively, when it was grazed by Angora-type goats. The companion legume, 'Tahora' white clover, also reduced by 20% its total of DM during spring, but it did not show any reduction of DM in summer or autumn. The companion grass, 'Maru' phalaris, had 80% of reduction of its total dry matter during summer.

Besides, the selectivity of grazing by goats at the top of the canopy may protect the growing points of chicory from damage. In Casey's experiment, the sward composition indicated that 60-70 percent of chicory was distributed over 10 cm height and, therefore, goats could have only grazed in the upper horizons causing no effect on the rosette.

2.7 CONCLUSIONS

The preceding literature review has revealed shortfalls in the knowledge of the importance of leaf remainder and chicory taproot. Similarly, potential companion species that might complement chicory's growth pattern have not been conclusively identified.

Given the potential for chicory to enhance production in New Zealand pastures it is clear that research is necessary to elucidate some of the fundamental agronomic principles in the effect of grazing on partitioning of dry matter between leaf, stem and taproot and hence on survival. It is also important to identify companion species that will enhance production per hectare of chicory pastures.

(a) January

(b) May

Plate 3.1a. Panoramic view of small plot trial, companion pasture species of chicory at Iversen Field, Lincoln University. (a) 12 January and (b) 12 May 1993

(c) August

(d) November

Plate 3.1b. Panoramic view of small plot trial, companion pasture species of chicory at Iversen Field, Lincoln University. (a) 12 August and (b) 12 November 1993

CHAPTER 3

RESPONSE OF CHICORY TO COMPANION SPECIES AT DIFFERENT SOWING RATES

3.1 INTRODUCTION

Chicory is winter dormant and this production gap could be filled by sowing another pasture species with chicory. Winter active grasses may do it but there is a risk that winter or early spring grazing could damage chicory taproots. On the other hand, chicory needs a nitrogen supply during the growing season to maintain fertility to achieve high production rates. Temperate legumes such as white and red clover appear to be good legume associates for chicory considering these can fix over 200 kg N ha^{-1} per year (Ledgard and Steele, 1992).

Chicory has been reported to be very competitive in mixtures with legumes (Kise *et al.* 1987; Casey, 1992) and grasses (Fraser *et al.* 1988; McFarlane, 1990). Individual studies involved only one sowing rate of chicory; furthermore, sowing rates varied from 1 to 7 kg seed/ha for stands sown with clover and 0.5 to 10 kg when sown in pasture mixtures which included grasses. Thus reported experiments do not provide sufficient data to allow recommendations for chicory sowing rates to be made with confidence. Given this inconclusive background information two small-plot experiments were established to investigate the response of chicory when sown at four sowing rates (0.75, 1.5, 3, or 6 kg seed/ha) in pure swards and mixed with different companion species.

3.2 MATERIALS AND METHODS

3.2.1 Description of experimental area

The experimental area, in Iversen Field, Lincoln University, had been sown in 1988 with a 'Grasslands Nui' perennial ryegrass-white clover pasture. Records of previous pasture management did not indicate any fertiliser use from 1988 onwards. The area was ploughed in autumn 1992 and remained fallow until it was used for the current research.

3.2.1.1 Soil characteristic

Soil was sampled on 23 August 1992 and analyzed for macronutrients (Table 3.1).

Table 3.1 MAF quick soil test of small plot trial area. Iversen Field. Lincoln University, Canterbury.

pH	Ca	K	P	Mg	Na	S
5.7	13	8	30	37	9	4

The soil was identified as a Wakanui silt loam of high fertility (Hewitt, 1992). According to Hewitt (1992) this soil belongs to the order Pallic, subgroup Mottled, and is characterized as having water deficits in summer and unpredictable heavy rainfalls in winter or spring. The soil test results indicated that it was a weakly acid soil with low lime requirements. Its nutrient status had medium K content, high P, very high Mg and low S content (McLaren and Cameron, 1990).

3.2.1.2 Weather conditions

Lincoln, Canterbury has a drought-prone, temperate climate. For the trial period, mean 1993 (760 mm) rainfall was similar to the 1992 rainfall (770 mm) and wetter than the long term mean (695 mm, 1930-1981). However September 1993 was unusual because it was three times wetter than the long term mean (47 mm) and, in contrast, October 1993 was 5 times drier than the long term (49 mm). Temperature characteristics of this area indicated these had similar trends to the long term means (Figure 3.1).

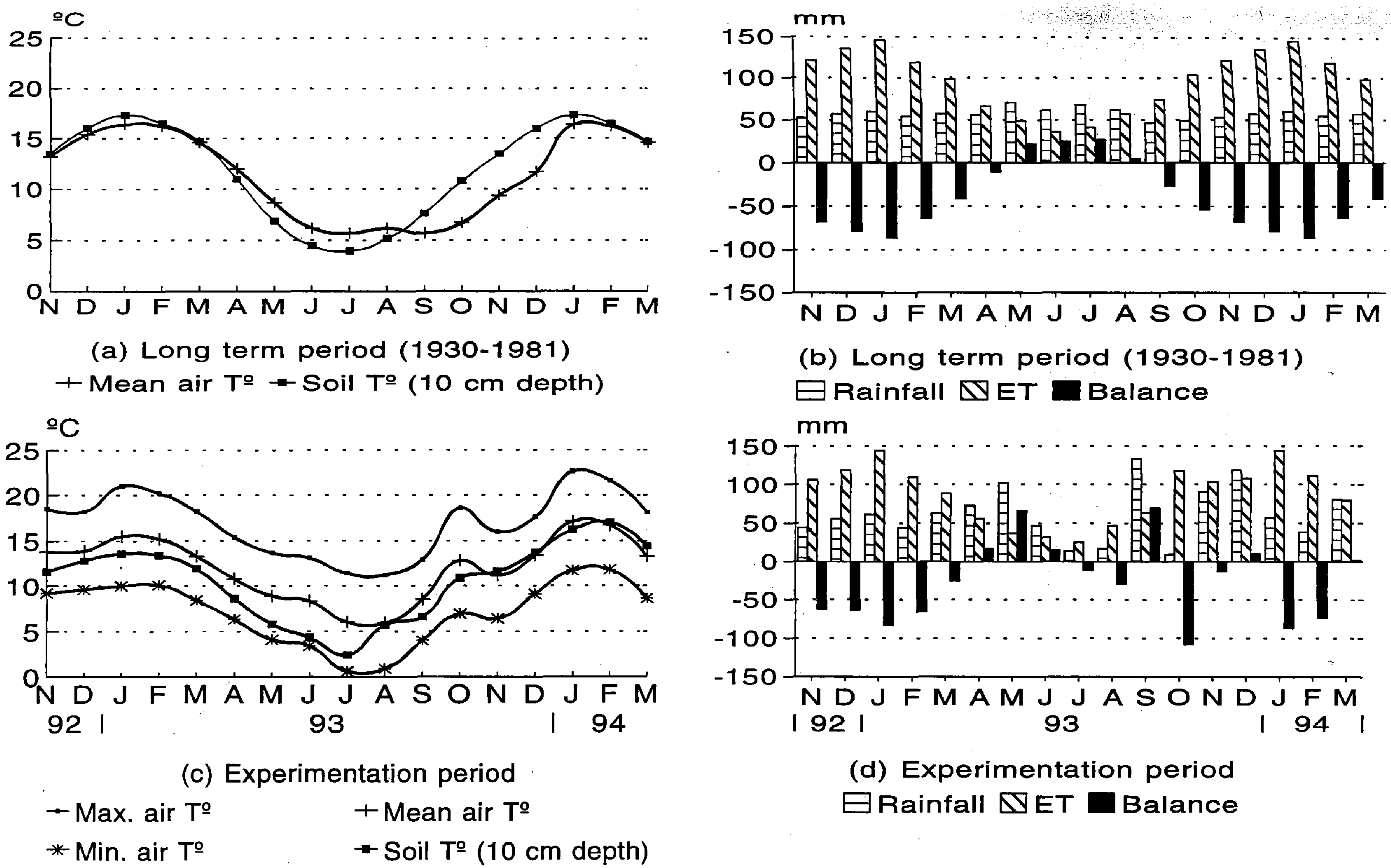


Figure 3.1 Monthly climate data for the Long term period (a and b) and the November 1992- March 1994 period (c and d). Broadsfield Meteorological Station, Lincoln, Canterbury.

3.2.2 Layout of experiments

3.2.2.1 Establishment

Two small-plot experiments were established on 30 November and 2 December 1992. The small plots were identified with wooden pegs numbered on their corners. Each small plot measured 1.5 m wide by 2.5 m length (3.75 m^2). Two raceways, each 4 m wide, separated the three replications within the main experiment.

'Grasslands Puna' chicory was sown at four sowing rates (0.75, 1.5, 3 or 6 kg seed/ha) either alone or in mixtures with companion species (Table 3.2).

Table 3.2 Viable seed sowing rates of companion species

Cultivar name	Common name	Scientific name	Sowing rate (kg/ha)
'Grasslands Kopu'	White clover	*Trifolium repens* L.	2
'Grasslands Pawera'	Red clover	*Trifolium pratense* L.	6
'Grasslands Matua'	Prairie grass	*Bromus Wildenowii* Kunth.	10
'Grasslands 'Maru'	Phalaris	*Phalaris aquatica* L.	2

Actual seed sowing rates were calculated after seed lots of each species were measured for thousand seed weight (TSW) and tested for germination according to ISTA (1985) (Table 3.3) in a SANYO incubator (MIR 152).

Table 3.3 Thousand seed weight and percentage germination

Grasslands cultivar	TSW (g)	Germination (%)
'Puna'	1.63±0.16	67.5± 0.7
'Kopu'	0.60±0.04	92.3± 4.0
'Pawera'	3.48±0.20	93.6± 2.3
'Matua'	10.57±0.70	51.0±10.5
'Maru'	1.42±0.08	68.0±15.9

Mean of three replicates ± SE_m

TSW = Thousand seed weight

3.2.2.2 Treatments

Experiment A had twenty seven treatments with pure swards (8), binary mixtures (10), complex mixture (8) and one unsown treatment containing invader plants (Table 3.4a). Experiment B had eight treatments where chicory and grasses were sown in binary mixtures (Table 3.4b). The period of experimentation was from 30 November 1992 to 24 December 1993.

TABLE 3.4 a Treatments of experiment A.- Chicory mixed with legumes or grasses

TREAT	CODE	MAIN TREATMENT CHARACTERISTICS
1	V	No plants : Weeds
2	W	'Kopu' white clover
3	R	'Pawera' red clover
4	B	'Matua' prairie grass
5	P	'Maru' phalaris
6	WB	'kopu' white clover + 'Matua' prairie grass
7	WP	'Kopu' white clover + 'Maru' phalaris
8	C0.75	'Puna' chicory (0.75 kg/ha)
9	C0.75W	'Puna' chicory (0.75 kg/ha) + 'kopu' white clover
10	C0.75R	'Puna' chicory (0.75 kg/ha) + 'Pawera' red clover
11	C0.75WB	'Puna' chicory (0.75 kg/ha) + 'Kopu' white clover + 'Matua' prairie grass
12	C0.75WP	'Puna' chicory (0.75 kg/ha) + 'Kopu' white clover + 'Maru' phalaris
13	C1.5	'Puna chicory' (1.5 kg/ha)
14	C1.5W	'Puna chicory' (1.5 kg/ha) + 'Kopu' white clover
15	C1.5R	'Puna chicory' (1.5 kg/ha) + 'Pawera' red clover
16	C1.5WB	'Puna' chicory (1.5 kg/ha) + 'kopu' white clover + 'Matua' prairie grass
17	C1.5P	'Puna' chicory (1.5 kg/ha) + 'Kopu' white clover + 'Maru' phalaris
18	C3	'Puna' chicory (3 kg/ha)
19	C3W	'Puna' chicory (3 kg/ha) + 'Kopu' white clover
20	C3R	'Puna' chicory (3 kg/ha) + 'Pawera' red clover
21	C3WB	'Puna' chicory (3 kg/ha) + 'kopu' white clover + 'Matua' prairie grass
22	C3WP	'Puna' chicory (3 kg/ha) + 'Kopu' white clover + 'Maru' phalaris
23	C6	'Puna' chicory (6 kg/ha)
24	C6W	'Puna' chicory (6 kg/ha) + 'Kopu' white clover
25	C6R	'Puna' chicory (6 kg/ha) + 'Pawera' red clover
26	C6WB	'Puna' chicory (6 kg/ha) + 'Kopu' white clover + 'Matua' prairie grass
27	C6WP	'Puna' chicory (6 kg/ha) + 'Kopu' white clover + 'Maru' phalaris

Table 3.4 b Treatments of Experiment B: Chicory and grasses

TREAT	CODE	COMPLEMENTARY TREATMENTS
28	C0.75B	'Puna' chicory (0.75 kg/ha) + 'Matua' Prairie grass
29	C0.75P	'Puna' chicory (0.75 kg/ha) + 'Maru' phalaris
30	C1.5B	'Puna' chicory (1.5 kg/ha) + 'Matua' prairie grass
31	C1.5P	'Puna' chicory (1.5 kg/ha + 'Maru' phalaris
32	C3B	'Puna' chicory (3 kg/ha) + 'Matua' prairie grass
33	C3P	'Puna' chicory (3 kg/ha) + 'Maru' phalaris
34	C6B	'Puna' chicory (6 kg/ha) + 'Matua' prairie grass
35	C6P	'Puna' chicory (6 kg/ha) + 'Maru' phalaris

3.2.3 Sampling period and measurements

3.2.3.1 Herbage mass

The trials were sampled seasonally (Table 3.5).

Table 3.5 Sampling times for experiments.

Season	Experiment A	Experiment B
Summer	24-28 Feb.	2-3 March
Autumn	15-20 May	20-22 May
Winter	16-17 August	17-18 August
Spring	15-19 November	20-21 November

Herbage mass was measured from one 0.2 m^2 sampling area per plot cut by hand to 15-mm, thus avoiding contamination from soil and litter. After each sampling, samples were fresh weighed and dissected for botanical composition. Components were dried at 70ºC for 48 hours before reweighing for dry matter (DM).

3.2.3.2 Plant counts

Seedling numbers were counted on 16 December, 15 January and 18 August 1993 by using three circular quadrats (0.0227 m^2 area) within each plot. Numbers of plants in pure chicory swards were also counted when taproot digging occurred in December 1993.

3.2.3.3 Taproots

Three taproots per plot were dug out only from pure chicory swards on 16 December 1993. These were washed and cut to a standard 150 mm length. Mean diameter of each taproot was measured at crown level. Taproots were put inside paper bags and oven-dried at 70ºC for seven days by which time constant weight had been achieved.

3.2.4 Management of experiments

The small plots were not fertilized. Irrigation (30 mm) was applied on 11 March 1993 to overcome drought conditions.

After the first sampling, plants were topped using a mower. However, mowing did not achieve uniform leaf removal. Subsequently, ewe lambs were used to clean up the plots; they took 6 days after the May sampling and 3 days after the August sampling.

3.2.5 Statistical analysis

3.2.5.1 Experimental design

Experiments A and B were analyzed separately as randomised complete block designs with twenty-seven or eight treatments, respectively. Both experiments had three replications. To compare data from the four times of sampling, a split-plot design was used identifying the sampling dates as main plots and sub-plots as treatments.

3.2.5.2 Analysis of data

Recorded data were analyzed using the MINITAB release PC version 8.2 (1991). The dry matter yields and botanical composition data have been collated, analyzed and presented in graphs as the mean of three replicates for pure chicory swards and in binary and complex mixtures with legumes and/or grasses for each sampling. Plant counts have been presented as the mean of three replicates of pure chicory plots only. Plant components have been indicated for chicory plants at the fourth sampling. Similarly, DM yields of chicory taproots were presented in line graphs from the pure chicory swards. Where appropriate the levels of statistical significance were indicated on tables or figures by presenting the standard error of mean (SE_m) at 5% probability or *P* values.

3.3 RESULTS

3.3.1 Herbage mass

3.3.1.1 Pure chicory

There were no significant differences between sowing rate treatments in chicory dry matter yields from any of the four cutting times reported (Figure 3.2). Trends suggested that the greatest DM yields came from the 3 kg/ha sowing rate.

In February, three months after the establishment period, chicory yields were low (Figure 3.2 a), May yields (Figure 3.2 b) from autumn growth were twice the February production and the August harvest (Figure 3.2 c) showed a marked yield reduction in response to low winter temperatures (Figure 3.1). In November (Figure 3.2 d) chicory yielded 580-900 g DM m^{-2} after the warm spring season.

Weed yields were greatest where chicory was absent at all cutting times except August. The lowest sowing rate (0.75 kg/ha) had greater weed yields in May and November than the higher sowing rates when chicory yielded much more than weeds (Figure 3.2 b and d). Weed yields were similar to chicory yields during the establishment period and after winter (Figure 3.2 a and c). Chicory sowing rate did not affect weed yields during those two periods. The dominant weed during establishment was the annual fathen (*Chenopodium album*). Perennial weeds such as dock (*Rumex obtusifolius*) were most common after February 1993.

3.3.1.2 Binary mixtures

Chicory and clovers

In general clover yields were low in binary mixtures with chicory (Figure 3.3 and 3.4). Chicory and clover yields tended to show an inverse relationship with increasing chicory sowing rates. For instance, clover yields were greatest at the 0.75 kg/ha sowing rate in November when chicory yields were less than at the two highest sowing rates. 'Pawera' red clover established better than 'Kopu' white clover and was higher yielding both with and without chicory.

Weed yields had marked differences between treatments at all cutting times; these were also greater than clovers in February and August (Figures 3.3 and 3.4).

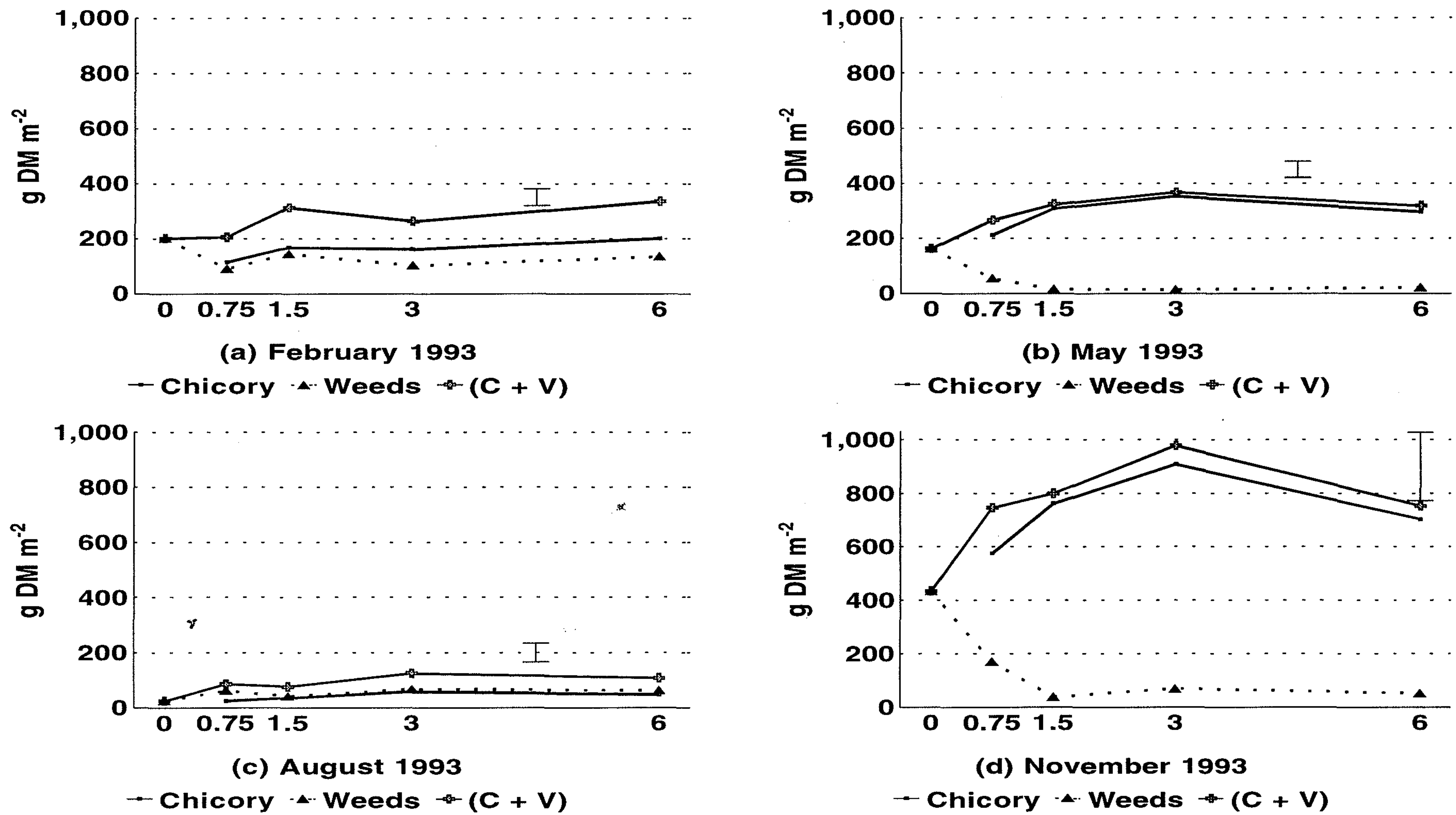


Figure 3.2 Dry matter yields of pure chicory swards at different sowing rates for (a) February, (b) May, (c) August, and (d) November 1993. Error bars= SE_m

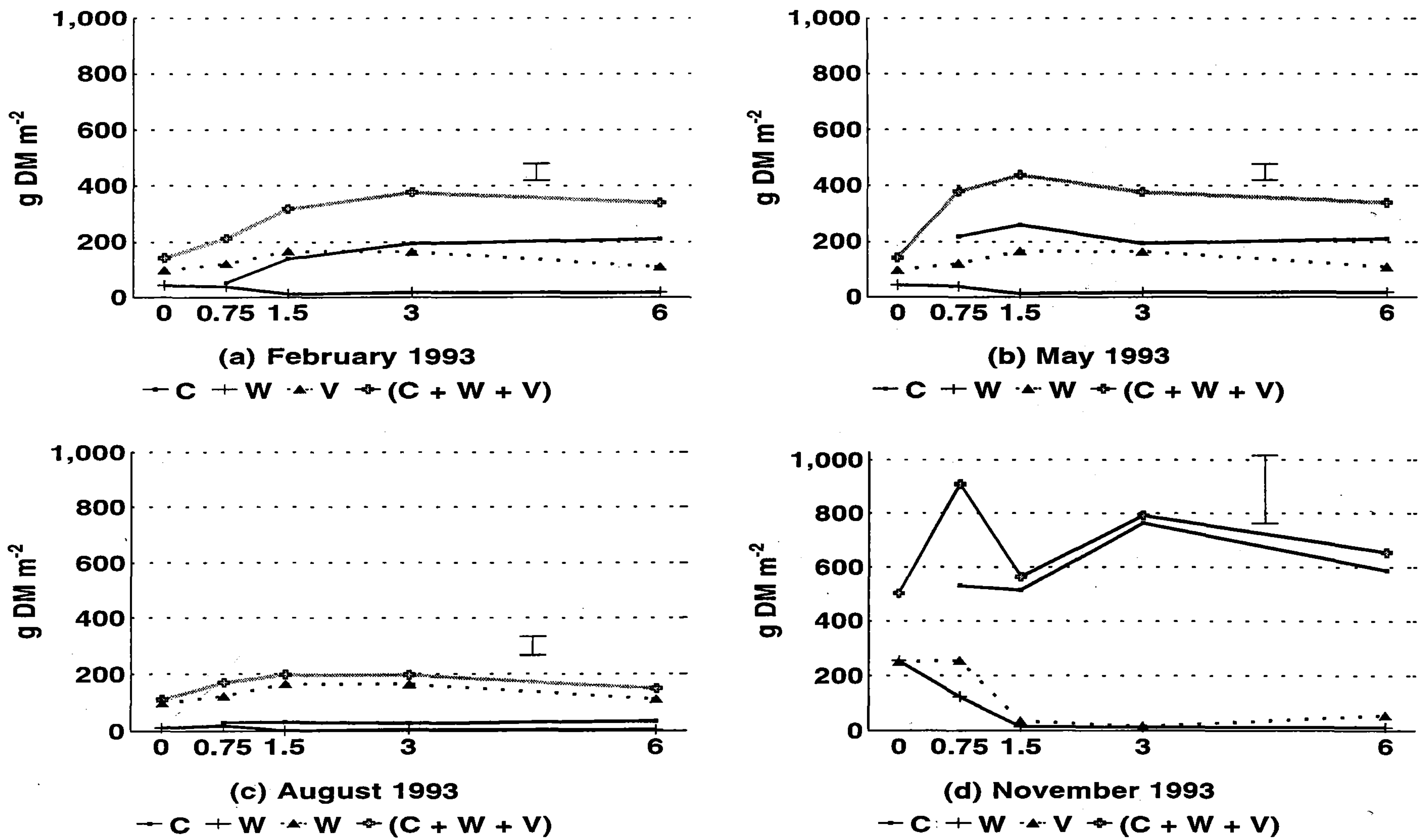


Figure 3.3 Dry matter yields of chicory (C) and 'Kopu' white clover (W) in binary mixtures for (a) February, (b) May, (c) August, and (d) November 1993. Error bars = SE_m

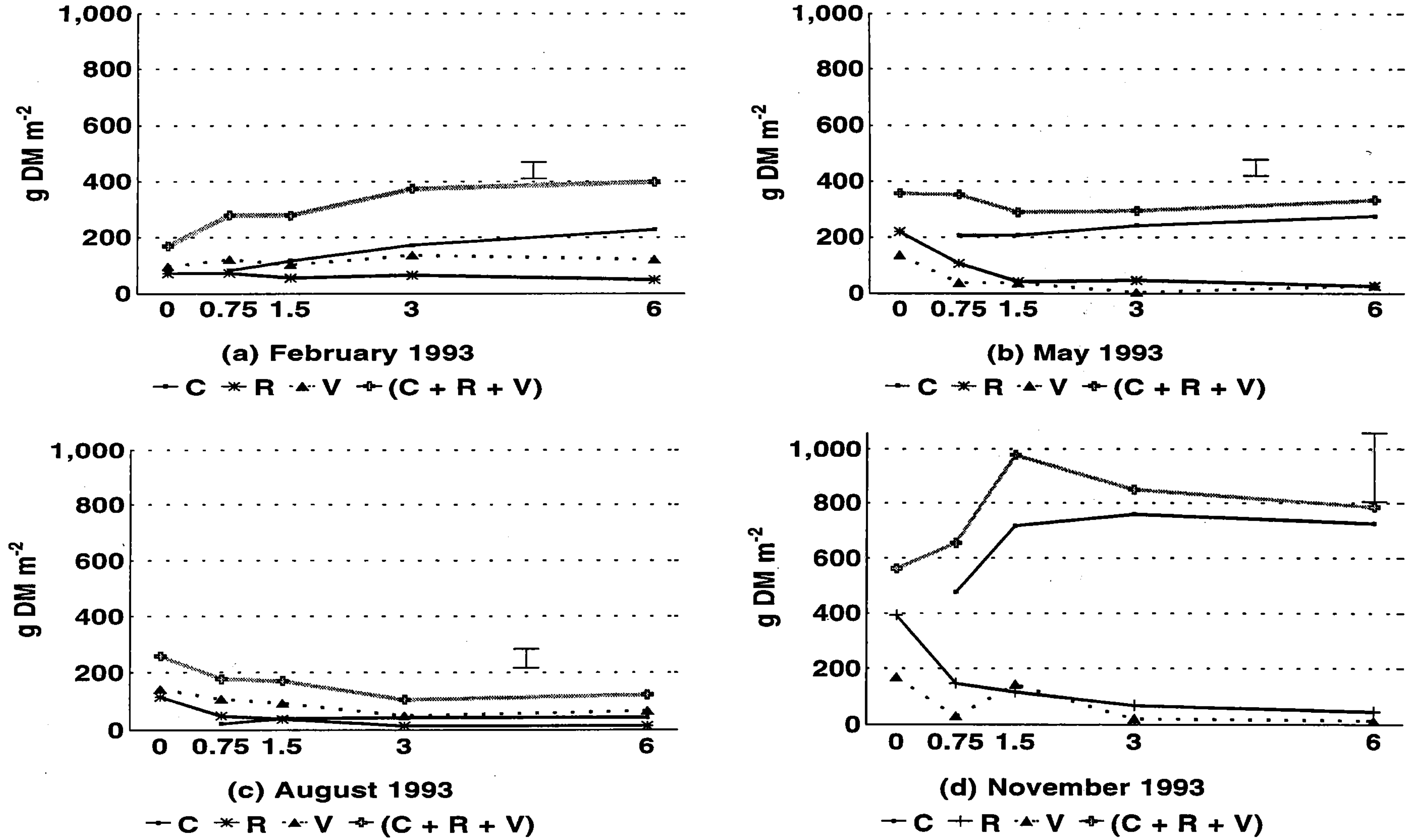


Figure 3.4 Dry matter yields of chicory (C) and 'Pawera' red clover (R) in binary mixtures for (a) February, (b) May, (c) August, and (d) November 1993. Error bars = SE_m

Chicory and grasses

In binary mixtures the two grasses tended to reduce chicory yields in comparison with pure chicory treatments. This effect was greatest at low chicory sowing rates (Figures 3.2, 3.5 and 3.6).

'Matua' prairie grass established faster than 'Maru' phalaris and was higher yielding than 'Maru' phalaris in the first three cutting times. 'Matua' was very high yielding (860 g m^{-2}) in November in the absence of chicory. However, 'Maru' phalaris had higher November yields than 'Matua' prairie grass when mixed with chicory.

Weeds were not a major problem in these mixtures during the four sampling seasons. Weeds were supressed at sowing rates greater than 1.5 kg/ha. There were greater weed yields in the mixture chicory-'Maru' phalaris than in chicory-'Matua' prairie grass.

3.3.1.3 Complex mixtures

The inclusion of 'Kopu' white clover with the grass plus chicory treatments did not greatly affect the pattern of dry matter yields over the range of sampling times and chicory sowing rates (Figure 3.7 and 3.8). 'Kopu' white clover yields were generally very low. Generally, chicory yielded higher than 'Matua' prairie grass and 'Maru' phalaris in all treatments.

The main difference between binary and complex mixtures was the increased weed yield in the complex mixtures at the February and August sampling times.

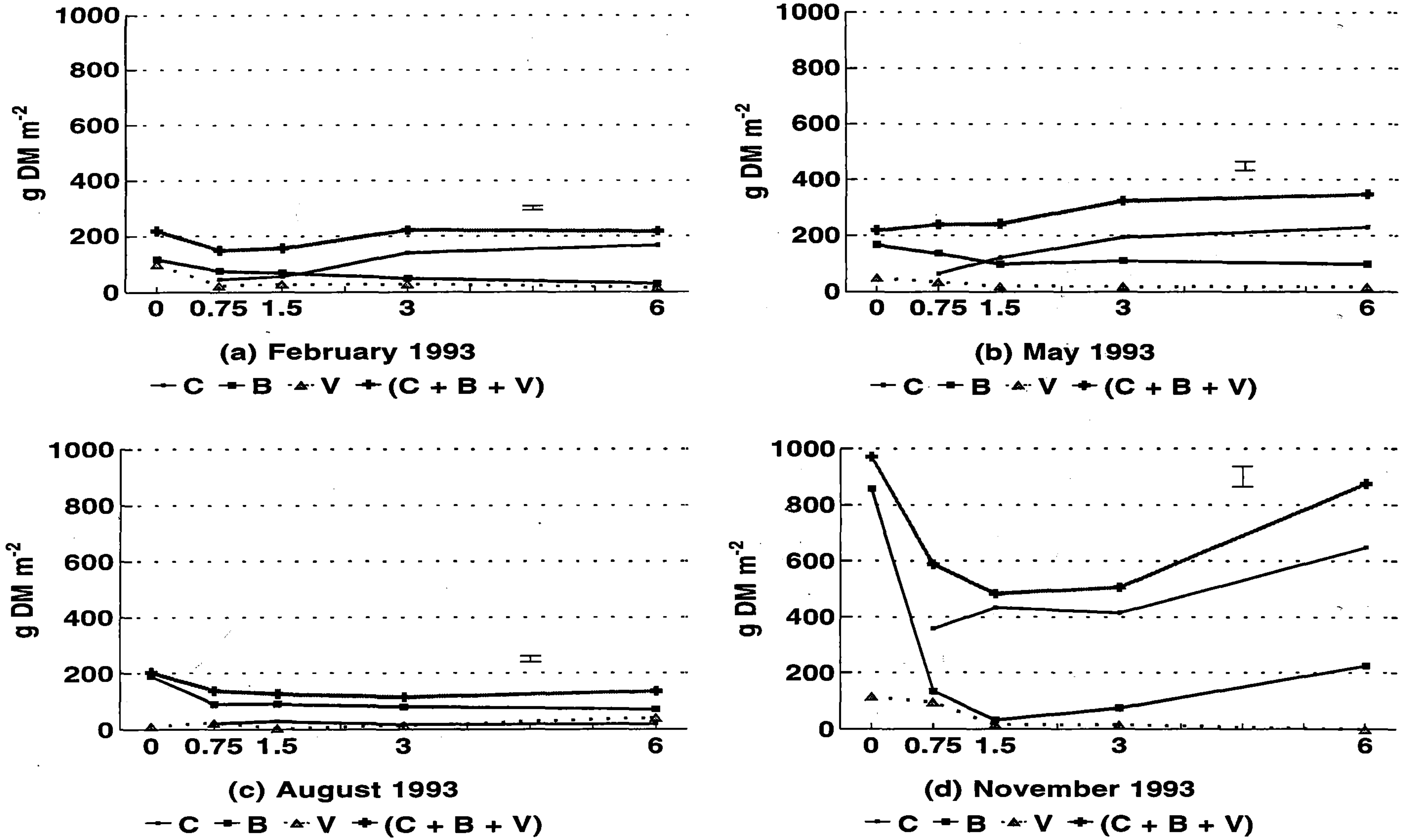


Figure 3.5 Dry matter of chicory (C), and 'Matua' prairie grass (B) in binary mixtures for (a) February, (b) May, (c) August, and (d) November 1993. Error bars= SE_m

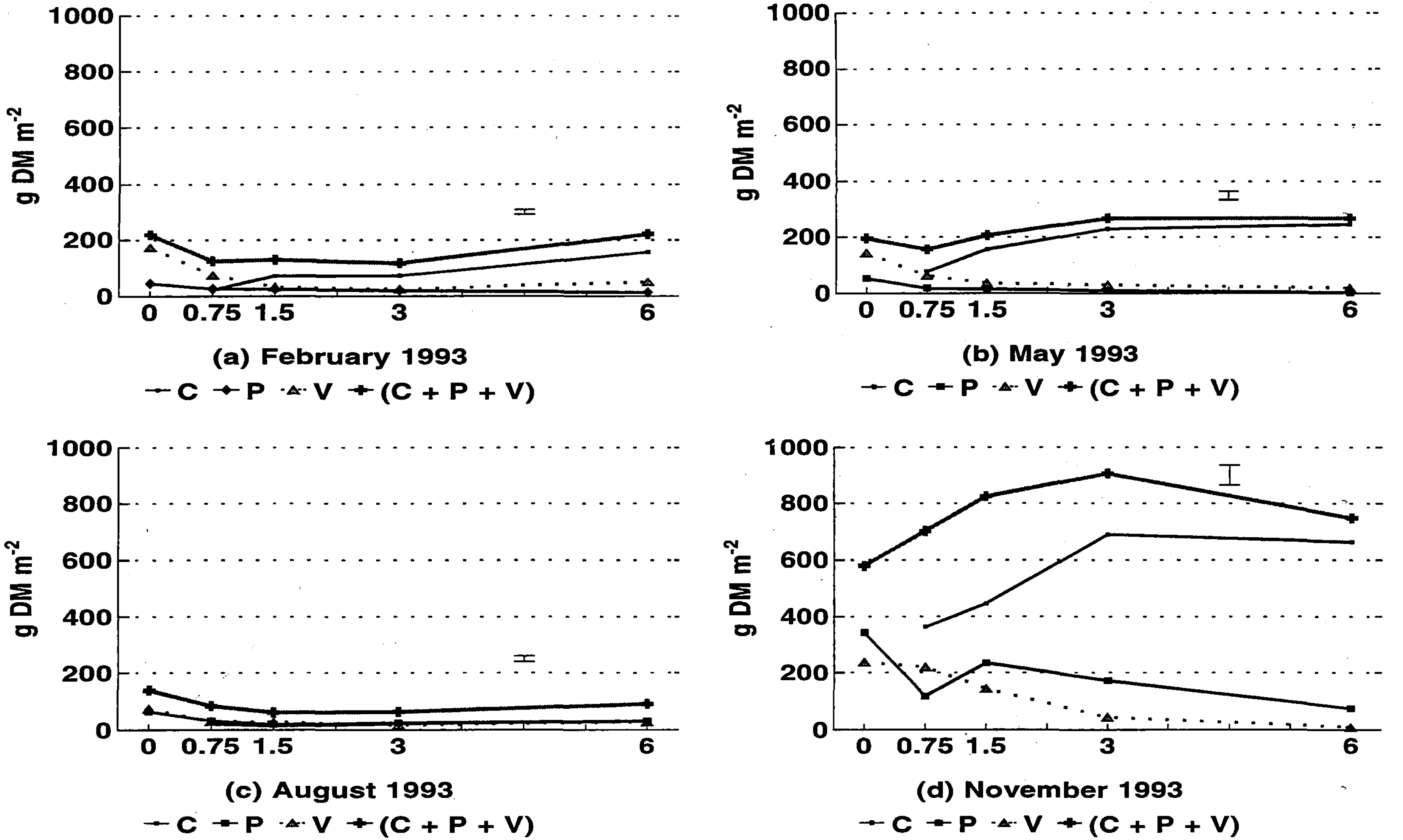


Figure 3.6 Dry matter of chicory (C) and'Maru' phalaris (P) in binary mixtures for (a) February, (b) May, (c) August, and (d) November 1993. Error bars= SE_m

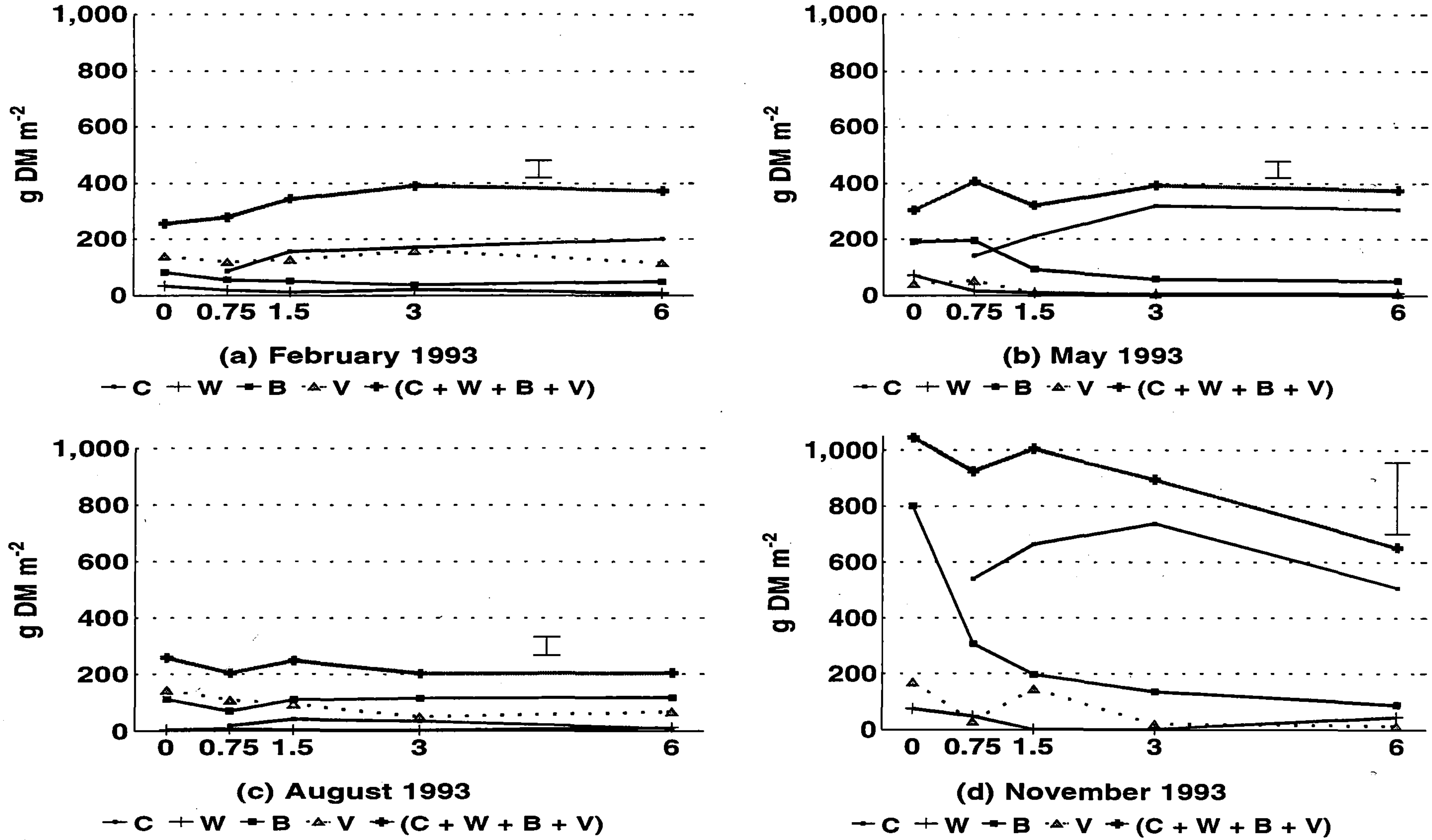


Figure 3.7 Dry matter yields of chicory (C), 'Kopu' white clover (W), and 'Matua' prairie grass (B) in complex mixtures for (a) February, (b) May, (c) August, and (d) November 1993. Error bars = SE_m

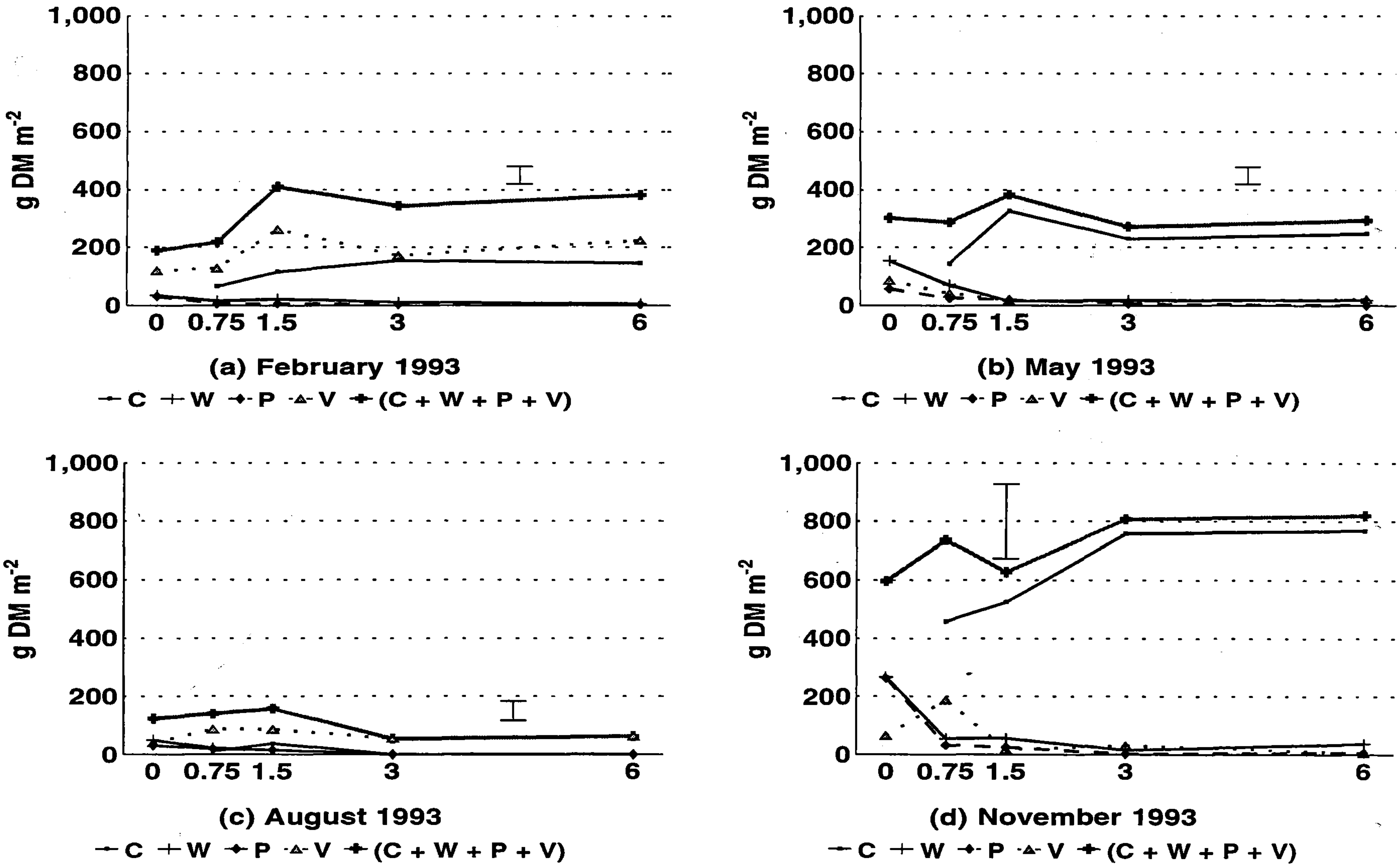


Figure 3.8 Dry matter yields of chicory (C), 'Kopu' white clover (W), and 'Maru' phalaris (P) in complex mixtures for (a) February, (b) May, (c) August, and (d) November 1993. Error bars= SE_m

3.3.2 Plant counts

3.3.2.1 Potential population

The potential numbers of seed sown per plant species (Table 3.6) were estimated from seed sowing rates presented in Table 3.3 and used to investigate the variation between the theoretical plant population and achieved population.

3.3.2.2 Pure chicory swards

Chicory plant population declined most over time at the higher sowing rates (Figure 3.9). More chicory plants (94%) survived in the 0.75 kg/ha sowing rate in August. The rate of mortality was 40-60% in January and it reached up to 56-75% in August at 3-6 kg/ha when compared with the initial seedling population.

Table 3.6 Numbers of viable seed sown per plant species per square metre at sowing. 30 November and 2 December 1992

<table>
<tr><th>Sowing rate (kg/ha)</th><th>'Puna' chicory</th><th>'Kopu' white clover</th><th>'Pawera' red clover</th><th>'Matua' prairie grass</th><th>'Maru' phalaris</th></tr>
<tr><td>0.75</td><td>68</td><td rowspan="4">361</td><td rowspan="4">184</td><td rowspan="4">185</td><td rowspan="4">207</td></tr>
<tr><td>1.5</td><td>136</td></tr>
<tr><td>3</td><td>272</td></tr>
<tr><td>6</td><td>545</td></tr>
</table>

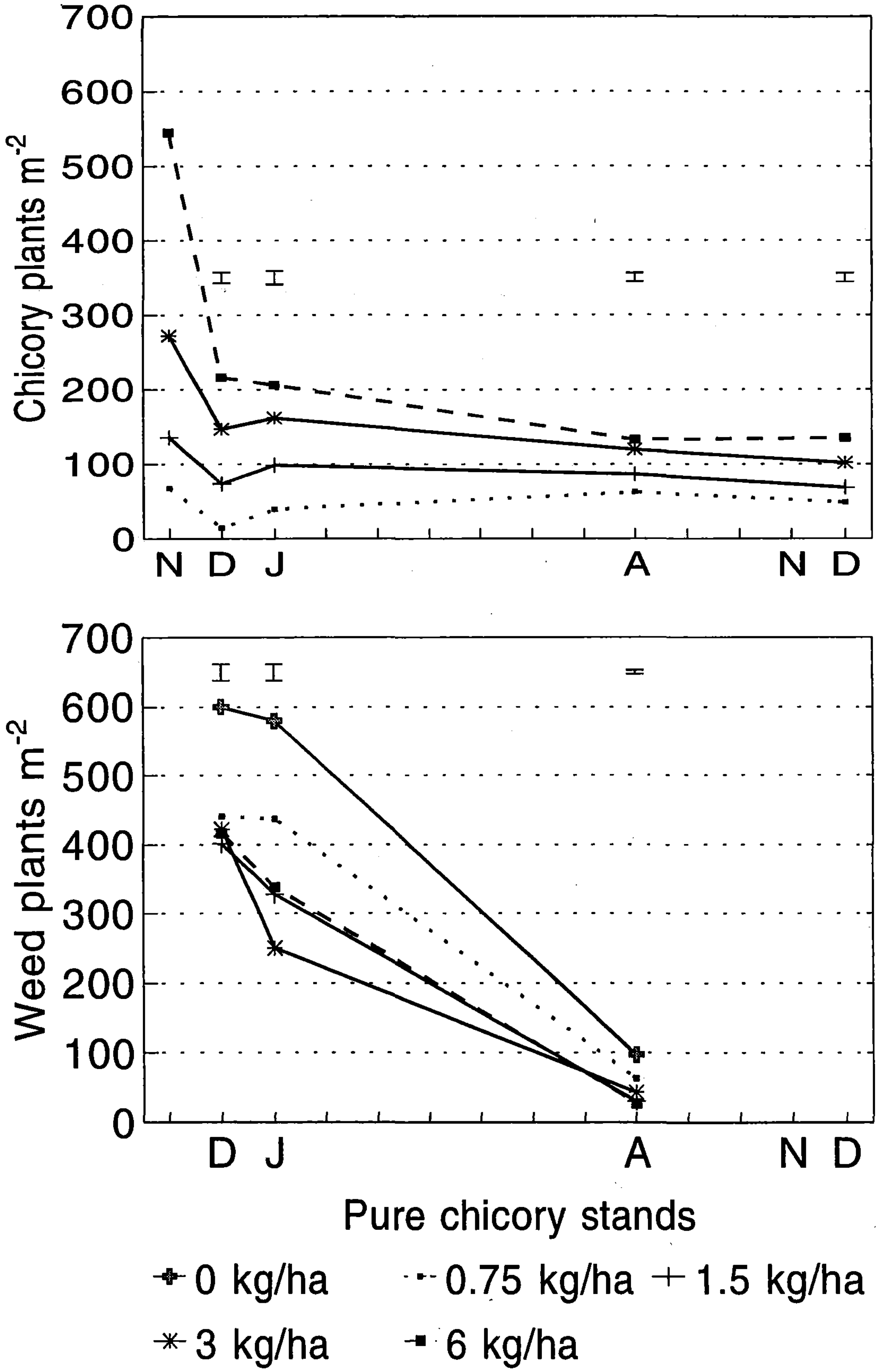


Figure 3.9 Number of seed sown (N) and achieved plants (D, J, A, and D counts) per square metre from pure chicory stands at four sowing rates. 1993. Error bars= SE_m

3.3.2.3 Binary mixtures

Chicory and clovers

In binary mixtures chicory and 'Kopu' white clover reduced their numbers of plants (Table 3.7) when compared with the estimated number shown in Table 3.3. Chicory plants survived by 85 percent in 0.75 kg/ha in August, but it reduced its plant population from 35-64% in January to 58-79% in August in 1.5-6 kg/ha. Meanwhile, plant number of 'Kopu' white clover was reduced from 43-67% in January and to 83-84% in August in the 1.5-6 kg/ha sowing rates.

Similarly, both chicory and 'Pawera' red clover reduced their number of plants in mixture (Table 3.8). However this mixture had more plants than the chicory-'Kopu' white clover mixture. At 0.75 kg/ha chicory had a great survival of plants in January (81%) but it was reduced to 64% by August. At sowing rates higher than 3 kg/ha chicory plants were reduced drastically from 47-55% in January to 69-86% in August in 3-6 kg/ha compared with the viable seed sown number.

Chicory and grasses

The mixture chicory-'Matua' prairie grass reduced drastically their number of plants even in low sowing rates (Table 3.9). In 0.75 kg/ha chicory plants survived by 75% in January, but these reduced to 49% in August. In higher sowing rates than 1.5 kg/ha chicory plants were reduced from 51-56% in January, to 50-77% in August when compared with the estimated plant population. On the other hand, 'Matua' prairie grass reduced its number of plants in the sowing rates 0.75-1.5 kg/ha (70-74%). However, this reduction was 64-66% in August. By contrast, in the 3-6 kg/ha sowing rate, 'Matua' plants were reduced from 66-68% in January to 73-81% in August.

Table 3.7 Mean number of seedlings and plants per square metre from the chicory/white clover binary mixture.

Sowing rate (kg/ha)	December 1992			January 1993			August 1993		
	C	W	V	C	W	V	C	W	V
0	-	130	325	-	160	340	-	140	60
0.75	54	195	475	59	140	430	60	80	20
1.5	70	130	415	88	205	340	60	60	40
3	84	100	415	143	120	280	100	60	40
6	150	120	435	196	130	280	110	60	60
SE_m	7	12	12	9	10	12	6	5	3

Table 3.8 Mean number of seedlings and plants per square metre from the chicory/red clover binary mixture.

Sowing rate (kg/ha)	December 1992			January 1993			August 1993		
	C	R	V	C	R	V	C	R	V
0	-	35	460	-	70	410	-	70	40
0.75	30	110	330	50	70	370	40	60	40
1.5	100	40	310	110	50	275	50	40	50
3	110	70	310	120	60	290	85	50	20
6	265	100	455	290	60	250	80	45	20
SE_m	7	12	12	9	10	12	6	5	3

Similarly, the mixture chicory-'Maru' phalaris showed a great mortality of both plant species after the January sampling (Table 3.10). Thus chicory reduced its plant number from 50-53% in January to 65-66% in August in 0.75-1.5 kg/ha. Moreover, the reduction of chicory plants varied from 68-71% in January to 73-78% in August in the 3-6 kg/ha sowing rate. On the other hand, 'Maru' phalaris showed a different trend compared with 'Matua' prairie grass. Its mortality of plants was high at sowing rate rates higher than 3 kg/ha (57-86% in January and 79-82% in August).

3.3.2.4 Complex mixtures

There were no significant differences in the number of chicory plants in the C-W-B or C-W-P mixtures in the December count (Table 3.11). The mortality of chicory plants varied from 24-37% in January to 31-80% in August in 1.5-6 kg/ha. 'Kopu' white clover reduced its number of plants from 43-58% in January to 78-89% in August in 1.5-6 kg/ha. Moreover, 'Matua' prairie grass declined its population from 44-63% in January to 70-81% in August in 1-5-6 kg/ha.

In the mixture of chicory, 'Kopu' white clover and 'Maru' phalaris, plant population of each species (Figure 3.12) was also reduced compared with the theoretical number. Chicory had low mortality (19-27% in January and 41-57% in August) in 0.75-1.5 kg/ha. This was greater in sowing rates higher than 3 kg/ha (57-73% and 71-80% in January and August, respectively). 'Kopu' reduced its number of plants from 67% (January) to 91% (August) in 6 kg/ha. Although, its mortality was 56-27% in January, these were as high as 80-83% in August in 0.75-3 kg/ha.

Table 3.9 Mean number of seedlings and plants per square metre from the chicory/prairie grass binary mixture

Sowing rate (kg/ha)	December 1992			January 1993			August 1993		
	C	B	V	C	B	V	C	B	V
0	-	40	385	-	80	430	-	60	30
0.75	55	110	350	44	55	310	33	60	33
1.5	60	75	285	63	50	250	67	67	20
3	175	90	240	130	60	340	90	50	30
6	215	60	290	240	60	230	120	35	20
SE_m	9	7	25	8	6	29	7	8	4

Table 3.10 Mean number of seedlings and plants per square metre from the chicory/phalaris binary mixture

Sowing rate (kg/ha)	December 1992			January 1993			August 1993		
	C	P	V	C	P	V	C	P	V
0	-	60	340	-	44	420	-	77	60
0.75	35	80	320	34	50	340	23	47	50
1.5	73	60	275	63	54	290	47	67	50
3	100	70	330	78	88	350	70	40	40
6	190	60	340	170	30	330	120	40	30
SE_m	9	7	25	8	6	29	7	8	4

Table 3.11 Mean number of seedlings and plants per square metre from the chicory/white clover/prairie grass complex mixture

Sowing rate (kg/ha)	December 1992				January 1993				August 1993			
	C	W	B	V	C	W	B	V	C	W	B	V
0	-	213	74	423	-	319	151	368	-	87	57	20
0.75	54	260	107	328	49	166	93	378	72	78	47	25
1.5	73	132	49	319	103	151	78	441	93	38	35	15
3	118	191	29	389	172	162	103	279	93	43	50	20
6	143	122	25	328	348	206	69	284	108	53	55	30
SE_m	7	12	9	12	9	10	7	12	6	5	12	3

Table 3.12 Mean number of seedlings and plants per square metre from the chicory/white clover/phalaris complex mixture

Sowing rate (kg/ha)	December 1992				January 1993				August 1993			
	C	W	P	V	C	W	P	V	C	W	P	V
0	-	153	54	240	-	231	25	367	-	127	97	20
0.75	49	201	40	495	54	157	63	353	40	63	57	33
1.5	69	210	74	441	99	206	69	265	58	62	51	14
3	157	231	63	363	118	265	40	275	79	71	68	30
6	93	88	40	382	147	118	49	231	108	32	56	44
SE_m	7	12	9	12	9	10	12	12	6	5	12	3

3.3.3 Taproot weights and crown diameter

In pure swards chicory taproot weight significantly (P<0.027) declined with increasing sowing rates. Individual chicory taproots were four times the dry weight in 0.75 kg/ha than 6 kg/ha. There were no significant differences between taproot weights grown in the 3 and 6 kg/ha sowing rates. The taproot weights per square metre were 350 g DM m^{-2} for either 0.75 or 1.5 kg/ha and 270 and 260 g DM m^{-2} for 3 and 6 kg/ha, respectively. Crown diameter was reduced (P<0.000) in sowing rates higher than 1.5 kg/ha. Therefore mean crown diameter was much higher at 0.75 kg/ha (Table 3.13).

Table 3.13 Number of plants, individual taproot and per square meter weights, and mean crown diameter. 16 December, 1993.

Chicory sowing rate (kg/ha)	Number of plants m^{-2}	Taproot weight (g DM)		Crown diameter (mm)
		Individual	per m^2 (*)	
0.75	50	7.0	350	25.8
1.5	70	5.0	350	18.8
3	100	2.7	270	17.9
6	135	1.9	260	17.9
SE_m	12	1.3	-	0.6
Significance	**	**	-	**

(a) Data calculated multiplying number of plants by individual weights.

3.4 DISCUSSION

3.4.1 Establishment of chicory

Chicory appears to show a similar pattern of emerging seedlings either in pure sward or mixtures. However it had lower population in mixtures compared with pure swards. Several environmental stresses may reduce chicory population, but water deficit stress or plant shading seems to have been the most likely limiting factors in those populations.

3.4.1.1 Pure chicory swards

Chicory had greatest plant population in high sowing rates, but, in contrast, there was lower mortality rate in the low sowing rates. That is an expected result of plant competition because when some seedlings grow faster than others the most vigorous seedlings will produce a greater shadow than young plants (Davies and Evans, 1990). This may be evident and severe in fertile soils where small growing plants are suppressed when they are surrounded by tall plants.

3.4.1.2 In binary mixtures

Chicory plus clovers

Clovers had to compete with strongly growing chicory at all sowing rates. That effect was greatest at sowing rates higher than 3 kg/ha when chicory had more plants outnumbering clover plants. Between clovers, 'Kopu' white clover had a greater population than 'Pawera' red clover in the February and May samplings. Both clovers showed similar populations in August, except in the 3 kg/ha sowing rate.

Chicory plus grasses

When chicory was mixed with both winter active grasses chicory population was reduced by 10-40% when compared with the pure sward population.

However this reduction occurred at the highest sowing rates. These winter grasses also reduced their plant population at increasing chicory sowing rates in each sampling date. Both 'Matua' and 'Maru' had highest plant populations at sowing rates lower than 1.5 kg/ha.

3.4.1.3 In complex mixtures

The mixture chicory-'Kopu' white clover-'Matua' prairie grass improved the survival of chicory plants relative to pure swards, but it increased slightly the mortality of 'Kopu' white clover and 'Matua' prairie grass. Chicory had more surviving plants in the C-W-B mixture compared with the C-W-P mixture in the 3-6 kg/ha sowing rates in January. However there were no significant differences in their numbers by August. 'Kopu' white clover did not show much variation in the number of plants in both mixtures. The lowest plant number was counted in the 6 kg/ha sowing rate in the August count. Winter grasses had low populations at all times; 'Matua' had highest plant counts in January but a reduced number in August. However 'Maru' had invariably low numbers of plants.

3.4.2 Dry matter production of pure and mixed chicory swards

Hill (1971) suggested that a simple mixture is not likely to outyield a pure stand of the better component. He also supported the idea that mixtures are at a disadvantage compared with the better monoculture. In the current experiments, chicory yields were reduced at all different mixtures when compared with the pure chicory yields.

Chicory yields are reduced by intra- or inter-specific plant competition. Plant competition occurs when a resource becomes deficient inside a pasture in pure or mixed swards. This effect is increased and more complex when more than two species grow in a pasture. Since each plant species has their own demand for soil moisture, light interception or nutrient supply these can manifest some restricted growth in further growing times after sowings. In the current research soil analysis indicated no restriction for plant growth. However the mixtures C-B or C-P should compete for nitrogen and the opposite case could be when chicory was mixed with clovers.

Chicory suppresed white clover and to a lesser extent red clover in all treatments. At high chicory sowing rates white clover extended its petiols up to reach the canopy, but these were not long enough to appear over chicory plants.

Volunteer weeds played an important role during the first growth stages of the establishing pasture species. Weeds appeared as replacement species invading plots. It is assumed that weeds have occupied the site before the sown species of a mixture. For instance weeds are more likely adapted to the surrounding area and have more relative advantages than the newly established pasture species. Chicory establishment seemed to be critically endangered in January because of the weed competition. Broad-leaved weeds such as fathen (*Chenopodium album*) completely dominated the whole experiment area from late December to early January. However an earlier sowing could make a difference but a heavy rainfall month (81 mm, October 1992) would have affected their establishing in the 1992 spring season.

The kind of companion plants may count in reducing the chicory yields. Companion clover or grasses or volunteer weeds had to actively compete with chicory at different stages of growth. Therefore, this weed invasion produced low yields in the February sampling. In May, chicory reduced weeds which were low yielding compared with the February sampling. In August, chicory was still dormant and, therefore, plant growth rate was restricted. In this month, chicory yielded lower than the rest of sampling months and weeds overtook chicory over the full range of sowing rates. In November, chicory produced reproductive stems which contributed to its high total yields and completely dominated weeds.

3.4.2.1 Total annual yields of chicory and mixtures

Highest total herbage DM yields occurred at high sowing rates and the highest yield was produced by the chicory/white clover/prairie grass mixture. Chicory had lower yields mixed with white clover than with red clover. The binary mixture of chicory and grasses had low total annual yields compared with pure chicory at sowing rates lower than 3 kg/ha.

Table 3.14 Total annual yield* of pure chicory, binary mixtures and complex mixtures.

Sowing rate (kg/ha)	Pure chicory	Binary mixtures				Complex mixtures	
		C-W	C-R	C-B	C-P	C-W-B	C-W-P
0	-	490	800	1332	500	1370	897
0.75	940	1000	1165	943	680	1505	935
1.5	1270	1000	1335	935	980	1545	1190
3	1480	1325	1410	1090	1240	1650	1200
6	1250	1195	1408	1443	1220	1400	1240
SE_m	198						
Signif.	**						

* Without weed weights

3.4.2.2 Seasonal chicory yields

(A) Pure chicory swards

Chicory had two extremes of growth from very low DM yields in winter (August) and highest in spring (November). As in other treatments weeds reduced chicory yields in summer (February) but these were suppressed in autumn (May) when temperatures dropped down lower than 10ºC (Figure 3.1). Chicory had highest DM yields at the highest sowing rates during the spring growth. That growth was because there was not any early cutting and chicory grew up to develop reproductive stems. Tall chicory plants suppressed weed weights up to 90% in the highest sowing rates.

(B) Binary mixtures

Chicory and clovers

Clovers appeared to be more sensitive to weed competition than chicory. Clovers did not affect chicory yields as drastically as grasses but these had unexpected results, especially white clover. 'Kopu' white clover did not develop so much because it was extremely sensitive to chicory competition. However, 'Kopu' white clover was expected to have an erect upright growth because it was designed for dairy farming conditions (Moloney, *et al.* 1988). 'Pawera' red clover developed straight stems with the chicory canopy as a result of competition for light. This was more obvious seen in low sowing rates. 'Pawera' red clover did not develop in greater sowing rates than 3 kg/ha because the high chicory population covered the ground completely.

Presumably, 'Kopu' white clover was more likely to disappear than 'Pawera' red clover when mixed with chicory because of its smaller seeds. During emergence most seedlings were etiolated as result of shading cause by weeds and chicory plants. On the other hand, chicory grew more strongly producing reproductive stems in spring warm temperatures and it was extremely competitive reducing the clover yields.

Chicory and grasses

Mostly, grasses reduced chicory DM yields in all sowing rate treatments. Grasses did not show their potential yields. 'Maru' is thought to have a slow establishment (Rumball, 1980; Brown, 1989; Casey, 1992). Presumably, immature seeds are responsible for the delay in establishing 'Maru' (Reddy, 1992). 'Maru' phalaris mixed with chicory had little growth in the first three cutting times when it was expected to have greater DM yields.

Also it was expected that 'Matua' prairie grass would produce high DM yields in low winter temperatures of August but this did not occur. In November 'Matua' mixed with chicory declined by 84 and 96% its DM yields compared with 'Matua' alone. In average 'Matua' had higher DM yields than 'Maru' phalaris in all treatments. Both species did not show the expected results, although 'Matua' produced more DM than 'Maru' in August. DM yields in the second winter would be likely to be much greater than in the first winter once grass plants were better established.

Chicory increased its DM yields when the sowing rates increased in both mixtures. However, these yields were 50 percent lower than those produced in pure chicory swards.

(C) <u>Complex mixtures</u>

It should be emphasized that competition is a dynamic phenomenon that it increases when more than two identified components grow in a mixture (Hill, 1971). This statement can explain the poor performance of white clover in mixture with chicory and grasses. Mainly, during the November sampling, chicory dominated the mixtures and 'Kopu' white clover almost disappeared. Chicory looked a strongly competitive species because it produced large stems and its leaves placed in alternate cyclic position made a heavy shade canopy on the grasses and 'Kopu' white clover.

The more plant species are included in a mixture the more complex the competition for survival. Chicory dominated the mixture with 'kopu' and 'Matua' prairie grass or 'Maru' in the 1.5-6 kg/ha sowing rates in February, May and November cuttings. The complex mixture reduced the chicory yields in all treatments, except in the November sampling when it had highest yield.

'Kopu' white clover did not achieve good performance in mixture with chicory and grasses at all. It showed disappointing DM yields at the different sowing rates. 'Kopu' white clover was not a good companion species in these mixtures at all. 'Kopu' white clover yielded very low in all sampling months and it did not show significant differences among the whole sowing rate treatments.

'Matua' prairie grass mixed with chicory had similar trends of DM yields compared with the binary mixtures and it dominated the yields in August. 'Matua' produced high yields at low sowing rates (0.75 and 1.5 kg/ha). However, although 'Matua' showed greater yields in November, chicory suppressed grass yield at high sowing rates. On the other hand, 'Maru' had similar DM yield trends like 'Kopu' and it was an unsuccessful companion species with chicory in this first year. Weeds were not a problem, except when chicory was dormant or in low sowing rates.

3.4.2.3. Daily production rate of chicory

Daily production rate (DPR) of pure chicory varied from 13-22 kg DM in the summer growth from the seedling stand (February harvest) to 64-100 kg DM ha^{-1} d^{-1} in the spring growth (November harvest).

In binary mixture with clovers DPR of chicory was 60-85 kg DM ha^{-1} day^{-1} when mixed with white clover and 50-80 kg DM/ha when mixed with red clover in the spring growth. In contrast when chicory was mixed with grasses DPR declined down to 40-70 kg DM ha^{-1} d^{-1} when mixed with prairie grass and 40-77 kg DM ha^{-1} d^{-1} when mixed with phalaris.

These DPR are low compared with the 150 kg DM ha^{-1} d^{-1} reported by Lancashire and Brock (1983) in pure chicory swards. It is likely that similar production rates would have been achieved by chicory in these experiments if measurements had been conducted during the second summer.

3.4.3 Effect of sowing rate on taproots of pure chicory swards

The importance of DM accumulated within taproots have been stressed by Frese (1991) in root chicory. Something similar can be done in 'Puna' chicory swards. From the current experimentation DM yields of taproots have shown an inverse relationship with increasing sowing rates. Chicory plants did have plenty energy for regrowth in 0.75-1.5 kg/ha compared with plants growing in 3 or 6 kg/ha. The 3 kg/ha sowing rate seemed to be the critical point because highest DM yields of herbage mass occurred commonly at that rate. Although weed competition was not a problem in sowing rates higher than 3 kg/ha, it is presumed that the intra-specific competition reduced their ability to store root reserves.

3.5 CONCLUSIONS

The results of this experiment indicate that chicory sowing rates should not exceed 3 kg seed/ha for pure stands. Higher sowing rates result in intense intraspecific competition and chicory populations soon decline to about 100 plants per m^2. For mixtures with species such as 'Matua' prairie grass which have vigorous seedlings 1.5 kg/ha chicory seed should be adequate. In mixtures containing slow establishing species chicory seeding rate should be restricted to a maximum 1.5 kg/ha. Farming industry relies on grazing animal, thus early grazing management should aim to favour associated species if the chicory appears to be too competitive.

CHAPTER 4

RESPONSE OF CHICORY TO GRAZING MANAGEMENT

4.1 INTRODUCTION

Chicory is a pasture herb intolerant of intensive and frequent grazing (Rumball, 1986). It was assumed that chicory would behave like lucerne after defoliation with carbohydrates stored in taproots being mobilised for regrowth and that residual leaves would be unimportant (Janson, 1982). Archer and Tiezen (1986) made the generalisation that pasture plants can tolerate defoliation by accumulating carbohydrates in structures like taproots, crowns or stolons. Subsequently Clark *et al.* (1990a) showed that there was a reduction of chicory dry matter production under frequent rather than infrequent cutting. They also found that chicory reduced production when cut at ground level (Clark *et al.* (1990a) and Matthews *et al.*, 1990 had a similar result when it was heavily grazed. The latter effect was greatest when chicory was grazed in drought conditions but the depression in yield was reduced with long spelling times.

These two studies suggested that chicory may be dependent on residual leaf after cutting or grazing to produce photosynthates for regrowth. A question must therefore be asked about the importance of residual leaf for chicory recovery after grazing.

This chapter will describe the response of chicory to defoliation through ten grazing cycles. Two intervals between grazings and two severities of defoliation were applied in the factorial design. Dry matter yields, plant population, crown bud number and taproot size were measured. The objectives were to determine (i) whether residual chicory leaves enhance regrowth after grazing by sheep and (ii) if grazing management influences chicory crop persistence through a reduction in taproot size and subsequent plant death.

4.2 MATERIALS AND METHODS

4.2.1 Description of experimental area

Five chicory paddocks, sited near Lincoln University, were grazed by sheep to investigate the chicory response to defoliation in ten grazing cycles. The four 2000 m^{-2} paddocks in Block D1 (paddocks 19, 20, 21 and 24) had been unsuccessfully autumn sown with chicory seven months before the current research started. The 3900 m^{-2} paddock in Block D2 had been a subterranean clover (*Trifolium subterraneum* L.) and ryegrass pasture. Records of previous pasture management in both areas indicated no fertilizer use in the previous five years.

Soil type was a Templeton silt loam, order Pallic, of high fertility (Hewitt, 1992). Soil was sampled as described in 3.2.1.1 and results are shown in Table 4.1.

TABLE 4.1 MAF quick soil test of paddocks used for the chicory grazing trial.

Paddock	Rep	pH	Ca	K	P	Mg	Na	S
D1-19	1	5.5	6	25	38	33	7	8
D1-20	2	5.7	7	34	75	37	5	6
D1-21	3	5.8	7	33	103	39	5	5
D1-24	4	5.0	6	17	112	21	4	11
D2	5	5.8	9	10	24	19	5	3

Most soils were weakly acid and had low-medium sulphur levels, very high potassium and magnesium contents, and extremely high phosphorus (McLaren and Cameron, 1992). The abnormally high nutrient levels mark the sites of former pig and poultry production areas.

4.2.2 Characteristics and management of chicory paddocks

The paddocks were re-sown with chicory at 4.4 kg/ha sowing rate in early November 1992 after the failure of the autumn sowing. Each paddock was subdivided into four plots by permanent fencing (Table 4.2). The grazing area in each plot was adjusted because there were no chicory plants growing along the 1-m wide strips close to the main fence line.

TABLE 4.2 Dimensions of grazed plots

Paddock numbers	Measurements of each grazed plot			
	Wide (m)	Length (m)	Area (m^{-2})	Chicory area (m^{-2})
(D1) 19, 20, 21, and 24	15.0	34.5	518	480
(D2)	28.0	34.0	952	900

The chicory was not fertilized during the trial period. Irrigation was applied to replication 4 in March 1993 after grazing because of very dry conditions in the stony, shallower soil of that area. The amount of feed had been overestimated and the sheep grazed the chicory plants very hard in all treatment plots of that replicate during the March grazing. All other replicates in the March 1993 grazing and all other grazing times were managed successfully according to the protocol (Section 4.2.3).

4.2.3 Treatments

Two levels of intensity (H= hard and L= lax) and frequency (F= frequent and I= infrequent) of defoliation in a 2^2 factorial design gave four grazing treatments (Table 4.3).

TABLE 4.3 Treatments of the chicory grazing trial

INTENSITY	FREQUENCY	
	FREQUENT (F)	INFREQUENT (I)
HARD (H)	HF	HI
LAX (L)	LF	LI

Each paddock was a replication; thus each treatment was replicated five times. Replications were grazed sequentially because there were not enough animals to graze the whole experiment simultaneously. This happened in each of the ten grazing cycles (Table 4.4).

TABLE 4.4 Dates of grazing for ten grazing cycles.

Grazing cycle			Duration per grazing cycle	Treatments grazed
Nº	Started	Finished		
1	25 Jan 93	15 Feb 93	21	All
2	18 Feb 93	4 Mar 93	14	HF & LF
3	22 Mar 93	16 Apr 93	25	All
Winter break (from 16 April to 16 September 1993)				
4(a)	16 Sep 93	10 Oct 93	16	All
5(b)	11 Oct 93	25 Oct 93	10	HF & LF
6	5 Nov 93	21 Nov 93	14	All
7	13 Dec 93	23 Dec 93	16	HF & LF
8	6 Jan 94	20 Jan 94	10	All
9	31 Jan 94	8 Feb 94	14	HF & LF
10	17 Feb 94	26 Feb 94	8	All

(a) Grazing ceased from 23 to 29 September and

(b) Grazing ceased from 15 to 19 October because of cold, high rainfall storms.

Grazing durations varied between 1 and 4 days depending on numbers of sheep available and feed on offer for grazing. The numbers of sheep were adjusted according to chicory yields estimated from samples taken before each grazing. It was assumed that the sheep would eat 1.5 kg DM per head per day but that higher stocking rates would be needed to graze the hard grazing treatments to low residual pasture mass without any chicory leaf remaining. Residual herbage mass in lax grazed treatments ranged between 20-50 percent of that offered to the sheep. Thus different numbers of ewe hoggets grazed different chicory treatments to achieve the desired intensity of defoliation (Table 4.5). Note that large numbers of animals were sometimes required to achieve hard grazing in the last days of grazing.

TABLE 4.5 Mean number of sheep per treatment at the start (and at the end) of grazing in each cycle. January 1993 - February 1994.

Treatment	Grazing cycle									
	1	2	3	4	5	6	7	8	9	10
HF	20	10	10 (20)	30 (33)	25 (35)	10 (45)	40	10 (30)	45	15
LF	10	5	4 (0)	8 (5)	25 (15)	20 (10)	20	20 (10)	25	10
HI	20	*	21 (30)	30 (33)	*	40 (45)	*	30 (55)	*	61
LI	10	*	9 (4)	8 (5)	*	40 (10)	*	45 (10)	*	30

4.2.4 Characteristics and management of animals

Three different sheep breeds were used in the grazings. Coopworth ewe hoggets grazed the chicory in eight of ten grazing cycles. Perendale ewes were used during the grazing in early spring. Corriedale ewe hoggets grazed the chicory once in November 1993. The ewe hoggets were 1-2 years old and had a live-weight range between 35-50 kg.

Plate 4.1. Sorting chicory leaves (alive or dead) from pre-grazing samp

Sheep were drenched before the first and fourth grazing cycles and when a new sheep flock came into the trial. During the grazings of September and October sheep were removed from the plots to the lanes or raceways during heavy rainfalls or cold weather. This was because animals only tramped chicory and several shorn ewe hogget deaths occurred at that time.

4.2.5 Sampling period and measurements

4.2.5.1 Chicory yields

Two 0.2 m^{-2} samples were cut with hand shears pre- and post- grazing from each treatment plot. Harvest height was 15 mm to avoid contamination from soil, litter and animal dung. After each sampling, botanical analysis and drying were done as described in 3.2.3.1. Plant components were separated into leaf, stems, reproductive structures (flowers plus seed pods), and dead matter.

4.2.5.2 Plant counts

Numbers of chicory plants were counted in the same dry matter sampling areas as indicated in 4.2.5.1. before each grazing using two 0.2 m^{-2} quadrats per plot.

4.2.5.3 Taproots

Sampling of taproots was done in March and July 1993 and March 1994. One or two taproots were dug out adjacent to each of six predetermined points in 1993 and 1994, respectively. That is 6 taproots in March 1993 per plot and 12 taproots in July 1993 and March 1994. Taproots were measured and dried as described in 3.2.3.3. Diameters of crowns and crown bud number per plant were also recorded.

4.2.6 Statistical analysis

Data collected at each grazing cycle from five replications were analyzed separately in the randomised complete block (RCB) design with two (only frequent grazings) or four treatments (all treatments). Main effects or interactions from the factorial design were considered when all four treatments were compared.

Dry matter yields of plant components and plant counts were analyzed and presented as histograms or line graphs, respectively. Taproots were analyzed as three different groups of data and shown as histograms. Most emphasis was placed on the last taproot sampling.

The levels of statistical significance were indicated in tables or figures by presenting the standard error of mean (SE_m) at 5 % probability. Where appropriate main effects only are presented if the interaction was not statistically significant.

4.3 RESULTS

4.3.1 Total annual pre-grazing yield of herbage

The yield data from the first grazing were excluded from calculations of total yield per year. This was done because the young vegetative chicory plants were immature and yields were therefore low for that time of the year.

There were significant ($p<0.05$) differences in the total dry matter yield produced by chicory under the four grazing treatments (Table 4.6). Chicory produced greatest leaf yields under the LF grazing and lowest in the LI grazing treatment. However chicory produced proportionately more leaf (73 % of the total yield) under the HF treatment than under the lax grazing treatments (LF= 49% or LI= 33 %).

Chicory plants produced a high proportion of reproductive stems under the LF, LI or HI treatments (33-49 % of the total yield). Flowers and seed pods represented less than 8 percent of the total DM yield of chicory.

Table 4.6 Total pre-grazing chicory dry matter yield, chicory plant components, white clover, dead matter and herbage mass (g DM m^{-2} $year^{-1}$).

Treatment	Chicory				White clover	Dead matter	Total Herbage mass
	Leaf	Stem	Flower	Total			
HF	1450 (89)	173 (11)	0.0 (0)	1623 (100) [94]	25 [1]	80 [5]	1728 [100]
LF	1580 (55)	1175 (41)	82 (4)	2837 (100) [70]	548 [13]	669 [17]	4054 [100]
HI	1190 (57)	808 (39)	81 (4)	2079 (100) [83]	137 [6]	265 [11]	2481 [100]
LI	1120 (37)	1685 (55)	240 (8)	3045 (100) [80]	219 [6]	530 [14]	3794 [100]
SE_m	33.3	64.2	13.8	91.1	59.9	67.5	-

Yields are from 9 frequent or 5 infrequent grazings over twelve months from February 1993 to February 1994.

(*) Percentage of the total chicory yield.

[*] Percentage of the total yield of chicory, clover and dead matter

4.3.2 Seasonal production of herbage

4.3.2.1 Dry matter yields of chicory

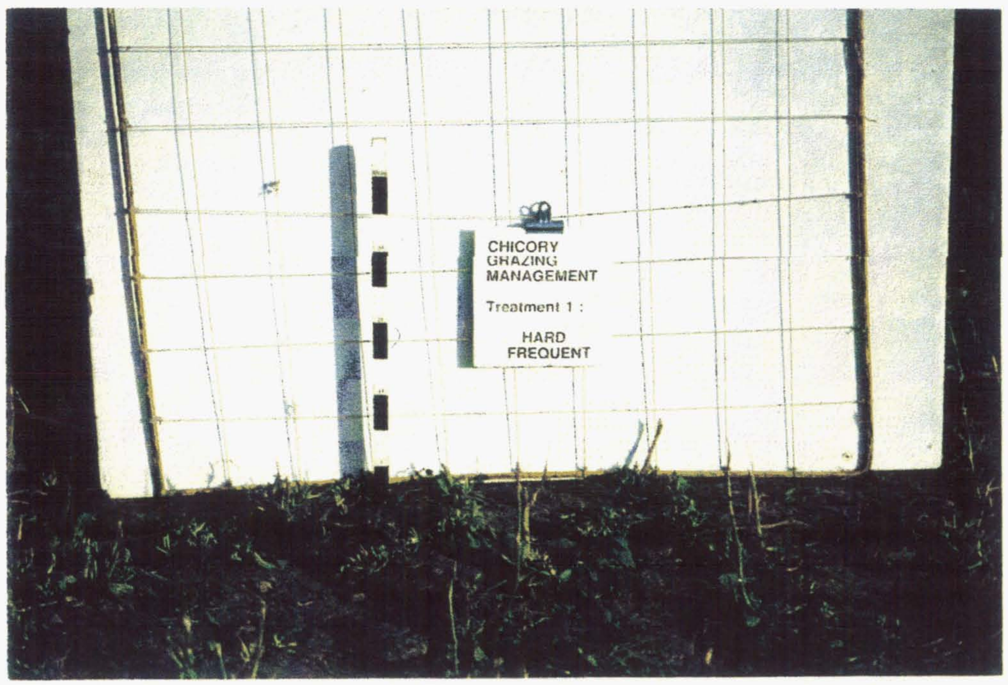
Pre-grazing dry matter on offer

The hard grazing treatments increased leaf production and reduced stem production compared with lax grazing treatments (Figure 4.1a,b, c, and d). Chicory produced up to 200 g leaf DM m^{-2} at the November harvest under the HF treatment but these were low leaf DM yields compared with the HI treatment (380 g DM m^{-2}) and the LI treatment (400 g DM m^{-2}). In later grazings leaf DM decreased down to 70-80 g DM m^{-2} in the lax grazing treatments or 100-150 g DM m^{-2} in the hard grazing treatments.

Reproductive stems appeared in late October. Chicory produced low reproductive stem yields under HF grazing compared with HI (100-180 g stem DM m^{-2}) or the lax grazing treatments (LF= 120-380 g stem DM m^{-2}; LI= 390-700 g stem DM m^{-2}). The LI grazing produced greater pre-grazing masses of upright primary stems than the LF, but there was a greater mass of secondary branched stems in the laxly frequent grazed chicory treatment. The LI treatment reproductive stems of chicory plants were brown colour by the ninth grazing cycle while chicory plants were flowering in the LF and HI treatments with green stems.

Mid-flowering was observed between late December 1993 and early January 1994 in the LI treatment. Chicory growing under the HI and LF grazing treatments had delayed flower appearance compared with the LI treatment. There was no evidence of flowering in the HF treatment. Reproductive structures were highest yielding under the LI treatment. Mature seeds were observed in the LI treatment compared with nil in the other grazing treatments.

(a) Pre-grazing



(b) Post- grazing

Plate 4.2. Appearance of chicory sward (a) pre- and (b) post- grazing in the hard frequent grazing treatment. Late February 1994.

(a) Pre-grazing

(b) Post- grazing

Plate 4.3. Appearance of chicory sward (a) pre- and (b) post- grazing in the lax frequent grazing treatment. Late February 1994.

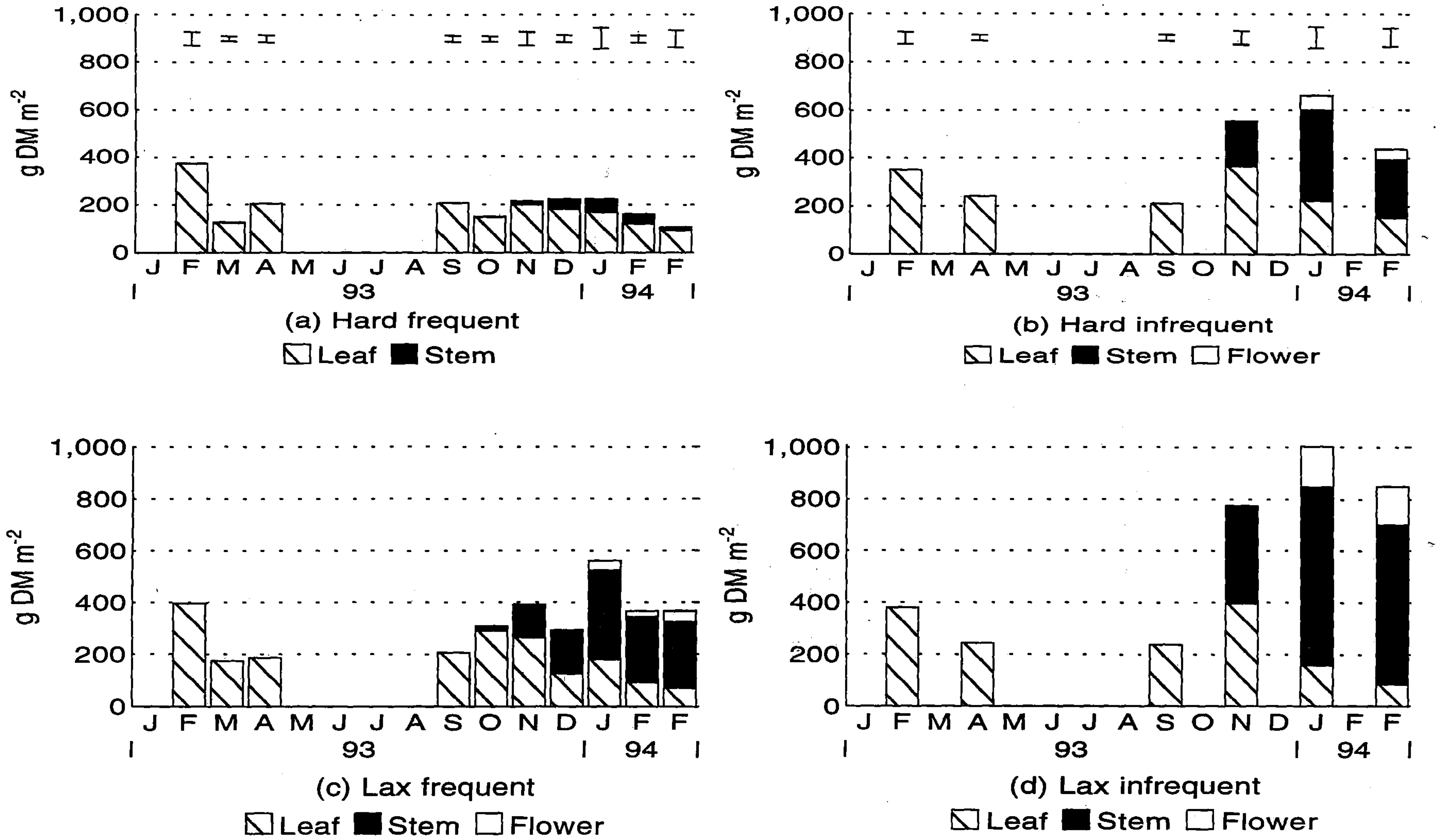


Figure 4.1 Pre-grazing dry matter yields of chicory components from four grazing treatments (a, b, c and d) from 25 January 1993 to 26 February 1994. Error bars= SE_m

Residual post-grazing dry matter

Plant material was almost completely removed from chicory plants in the hard grazing treatments during the first six grazing cycles (Figure 4.2a, b, c and d). At later grazings there were some remaining stems in the hard grazing treatments but these had lower weight than those in the lax grazing treatments. Both lax grazing treatments had high residual leaf yield after grazing in the grazing cycles of F, M, A, S and O. In later grazing cycles leaf residuals decreased as the proportion of reproductive stems increased.

4.3.2.2 Presence of volunteer white clover

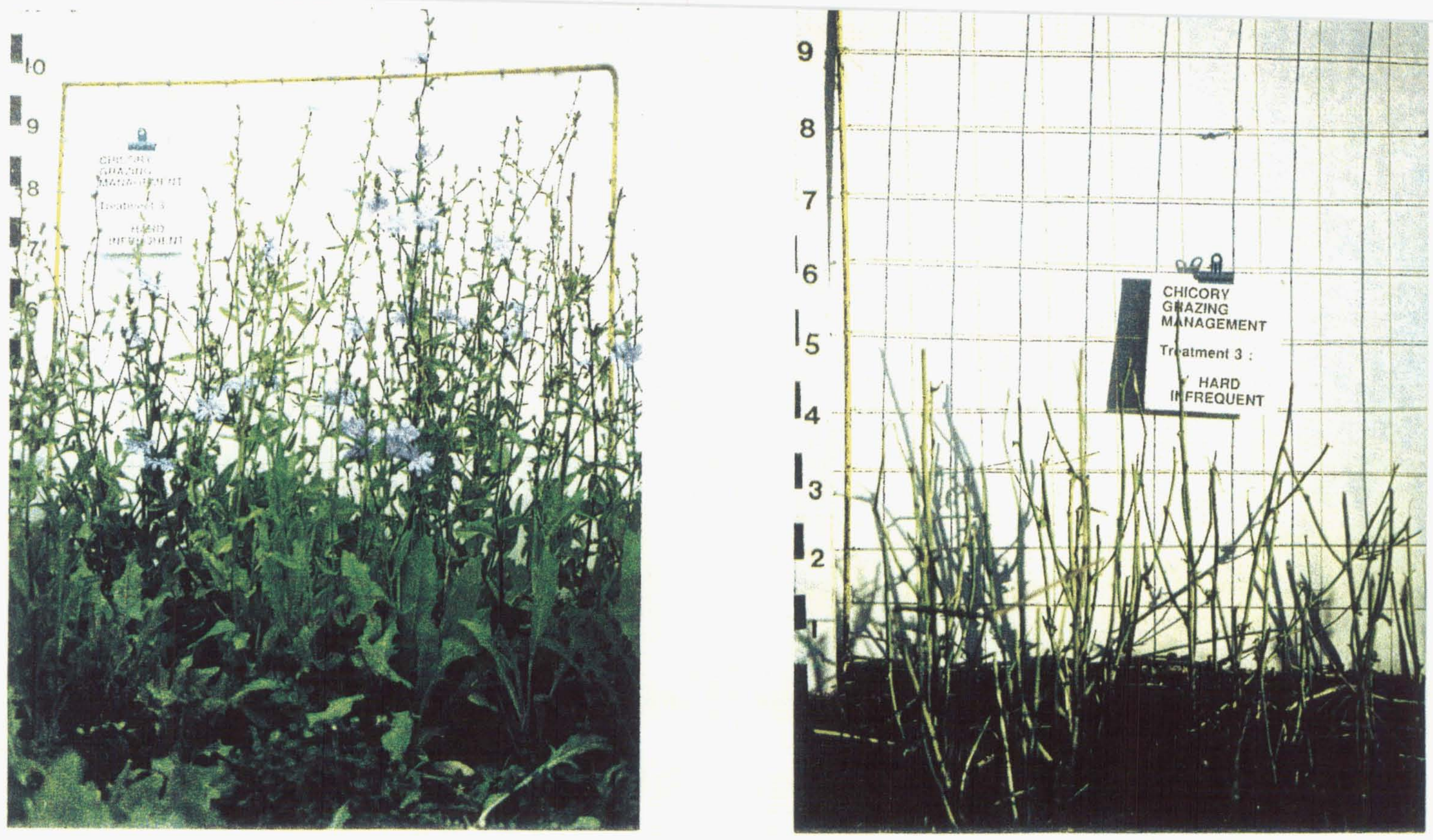
Pre-grazing dry matter on offer

White clover was the main volunteer species invading in three replicates in early spring 1993. Indeed the uneven distribution and relative lack of white clover in two replicates resulted in high standard errors of the means for this unpredicted pasture component. The presence of white clover varied significantly between the main effects of grazing intensity and frequency (Figures 4.3 a and b). It grew abundantly and vigorously under lax grazing compared with hard grazing.

Residual post-grazing dry matter

Volunteer white clover was rapidly eaten in hard grazing treatments and post-grazing herbage mass was very low (Figures 4.3 c and d). There was more white clover left after the lax grazings.

On the other hand white clover was grazed similarly in both frequent or infrequent grazing treatments. Thus there were not significant differences in the residual white clover DM left after grazing for the grazing frequency main effect.



(a) Pre-grazing

(b) Post- grazing

Plate 4.4. Appearance of chicory sward (a) pre- and (b) post- grazing in the hard infrequent grazing treatment. Lat February 1994.

(a) Pre-grazing

(b) Post- grazing

Plate 4.5. Appearance of chicory sward (a) pre- and (b) post- grazing in the lax infrequent grazing treatment. Late February 1994.

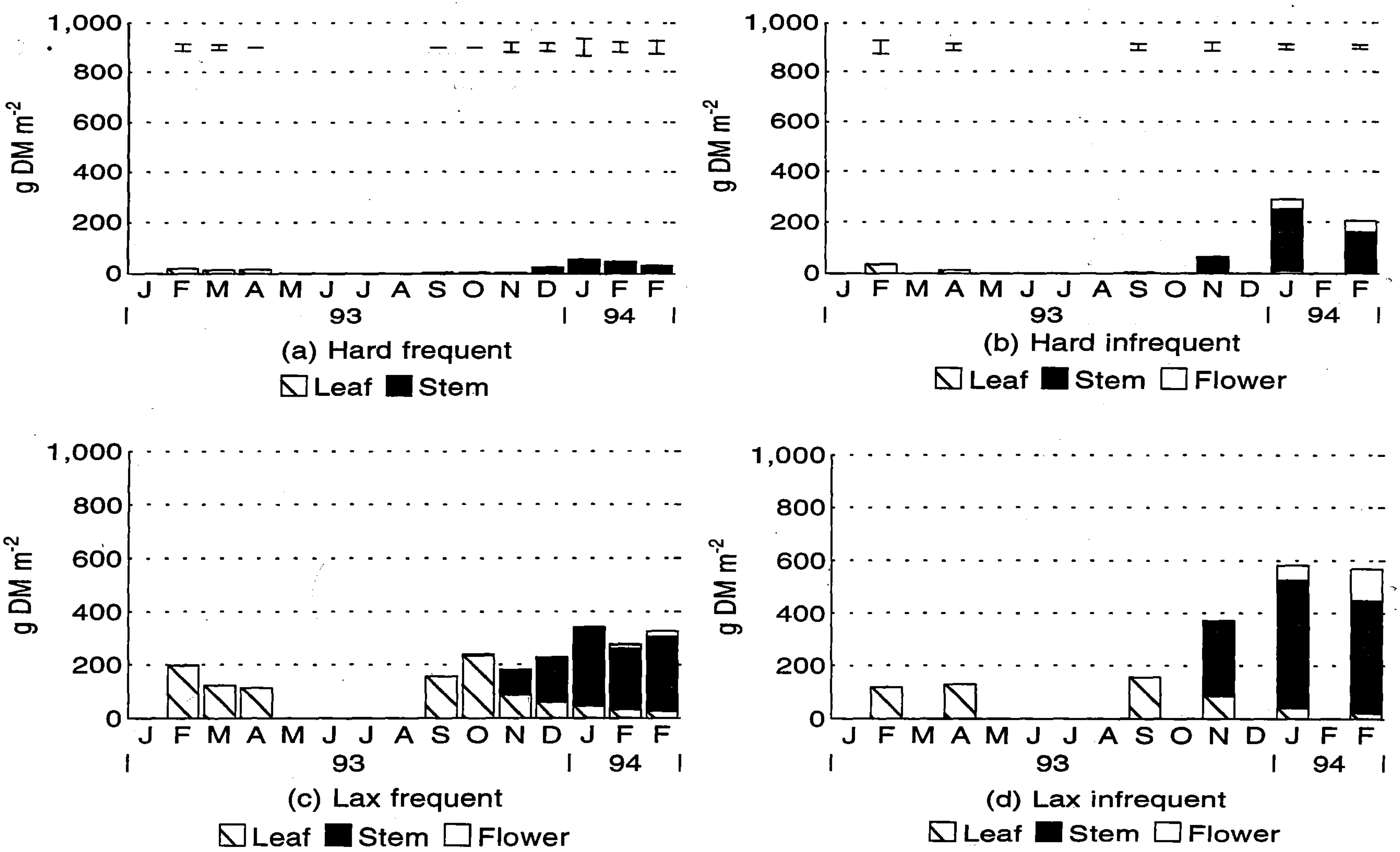


Figure 4.2 Post-grazing dry matter yields of chicory components from four grazing treatments (a, b, c, and d) from 25 January 1993 to 26 February 1994. Error bars= SE_m

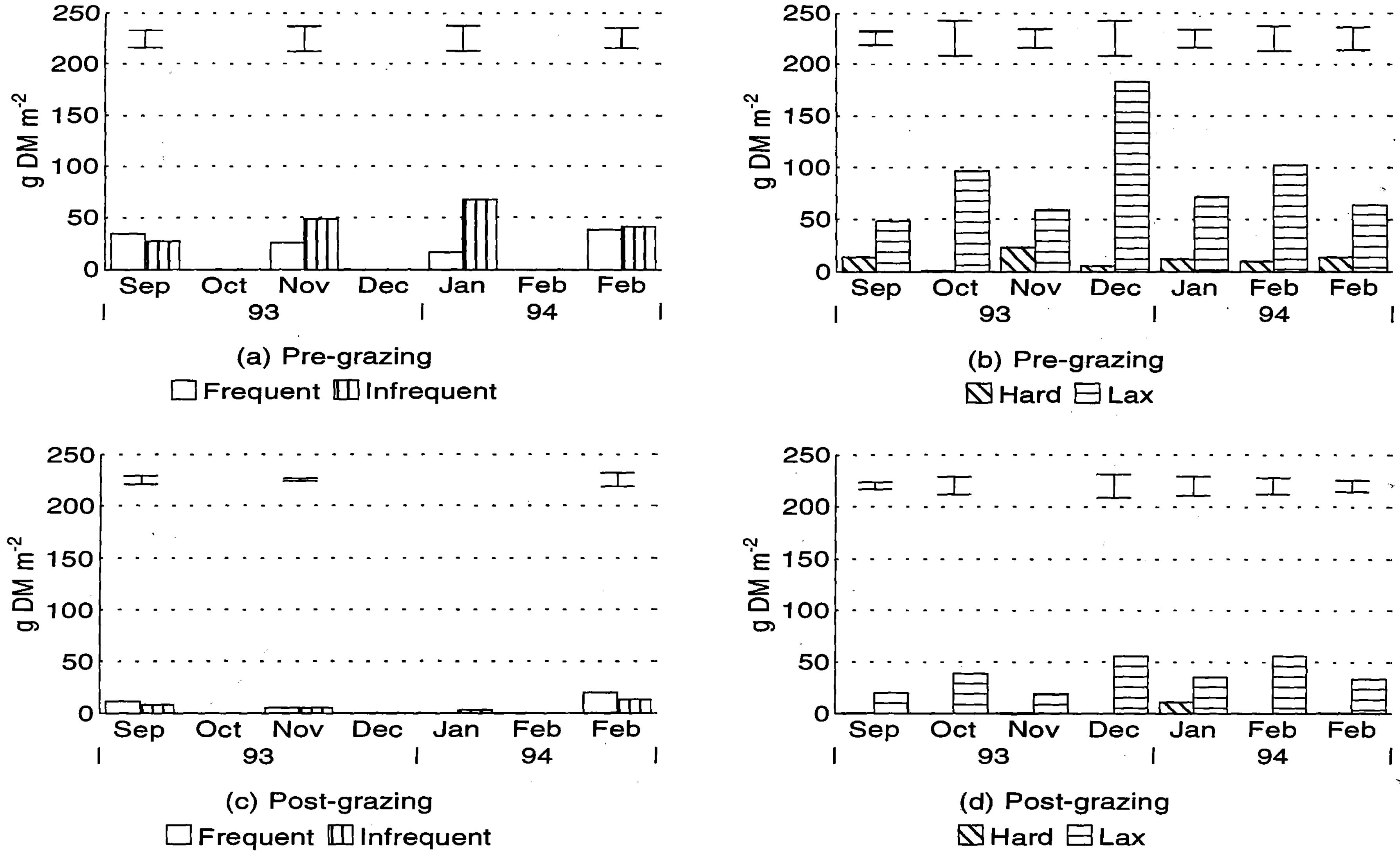


Figure 4.3 Pre-grazing and post grazing dry matter yields of white clover at the main effects of grazing frequency (a and c) and intensity (b and d) (from 16 September 1993 to 26 February 1994). Error bars= SE_m

4.3.2.3 Dead matter

There were significant differences in the dead matter component at the four grazing treatments (Figures 4.4 a, b, c and d). The hard grazing treatments in HF or HI had the lowest dead matter mass on offer. In the lax grazing treatments the main components of dead matter on offer were stems and to a lesser extent leaves from November 1993 to late February 1994. Meanwhile, in the HI treatment the dead stem and leaves constituted the dead matter.

4.3.3 Disappearance rate of herbage mass

4.3.3.1 Animal grazing days

There were significant differences between animal grazing days (agd) per treatment in each grazing cycle (Figure 4.5). The HI treatment always had higher values (80-135 agd) when compared with the lax grazing treatments (LF:10-55 agd or LI:30-90 agd) treatments which had the lowest values on average.

Hard grazing treatments had high grazing days in April 1993 (HF: 90; HI: 120 agd). HF treatment had most grazing-days in September (90 agd) and December (90 agd) 1993 than in later grazing cycles. HI treatment had the highest animal grazing days in November (135 agd) and it declined down to 100 agd at the late February grazing.

Lax grazing treatments had also high animal grazing days in November (LF= 50 agd; LI= 90 agd) but these were lower than those in the hard grazings. In most grazing cycles lax grazing treatments had low animal grazing days, for instance, in the LF treatment grazing days decreased down to 20 agd and in the LI treatment to 50 agd at late February.

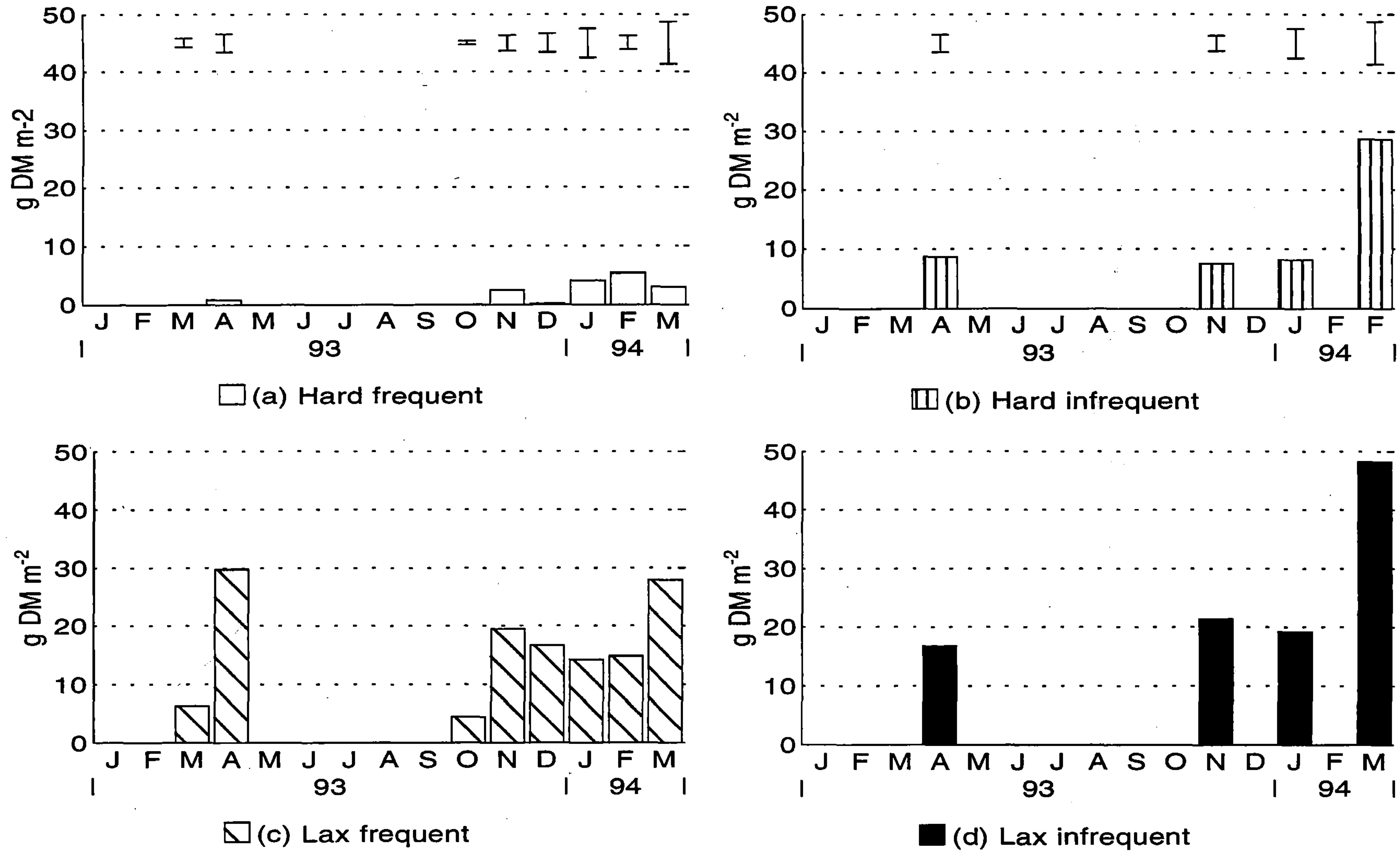


Figure 4.4 Dry matter yields of dead matter pre-grazing per grazing treatment (a, b, c, and d) from 25 January 1993 to 26 February 1994. Error bars= SE_m

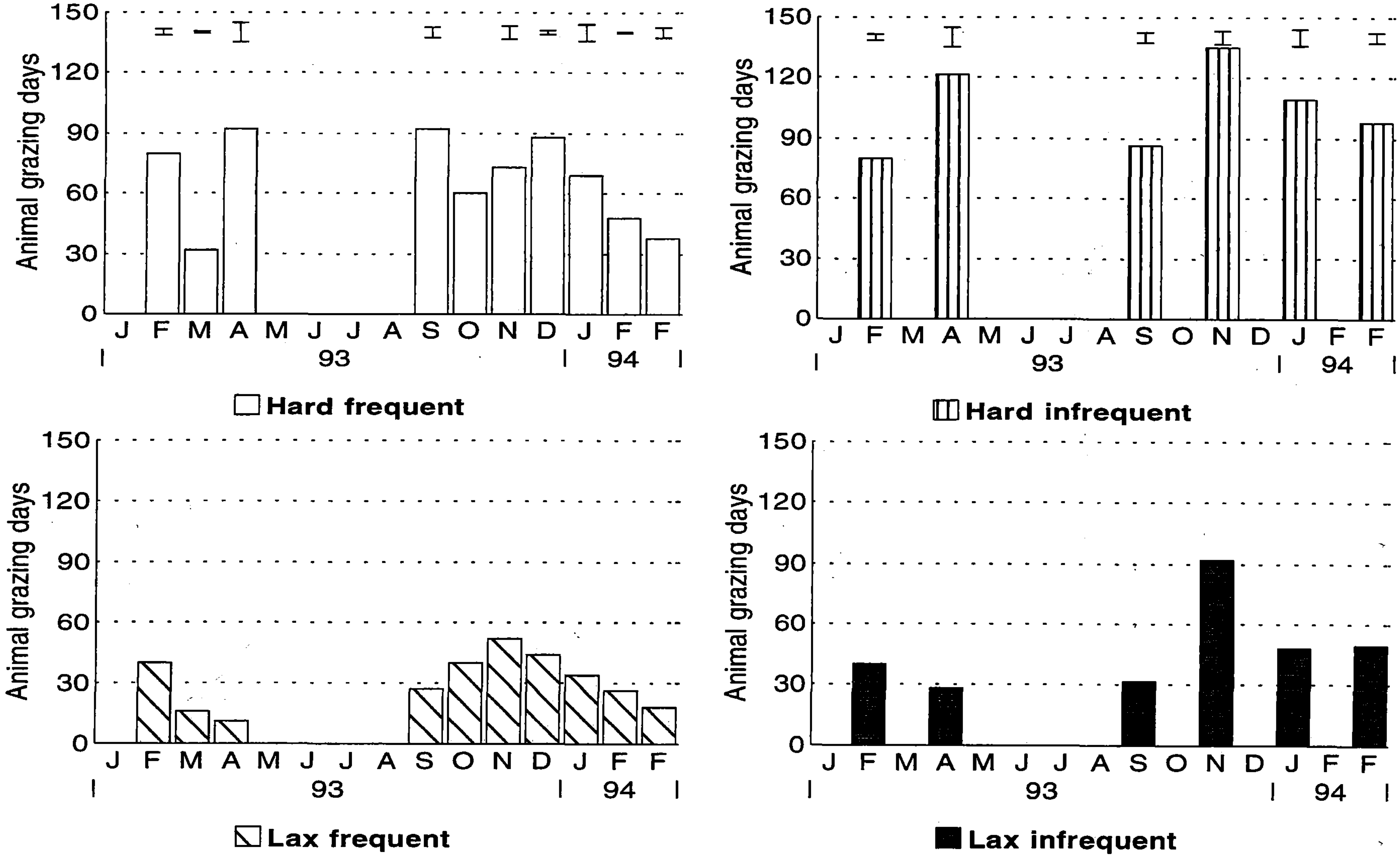


Figure 4.5 Grazing days per grazing treatment from 25 January 1993 to 26 February 1994. Error bars= SE_m

4.3.3.2 Disappearance rate of chicory

Chicory had significantly different rates of disappearance in all four grazing treatments (Figures 4.6 a, b, c and d). These were much higher in LI where high dry matter yields resulted from stem production from the November grazing. It is unlikely that sheep grazed only chicory so they could also graze white clover.

4.3.3.3 Disappearance rate of volunteer white clover

Volunteer white clover had a significantly high disappearance rate between the main effects of grazing intensity. Ewe hoggets grazed more white clover in lax grazing compared with hard grazing treatments (Figure 4.7 a).

On the other hand the main effect of grazing frequency indicated that ewe hoggets grazed more white clover at frequent rather than infrequent grazing treatments (Figure 4.7 b).

4.3.4 Chicory plant population

There were more chicory plants under hard grazings compared with the lax grazing treatments (Figure 4.8). The final plant population of chicory was 78, 63, 55 and 48 plants m^{-2} in the HF, HI, LF, and LI, respectively. The great decline of chicory plants started in early spring and it appeared to be caused by an outbreak of *Sclerotinia*.

4.3.5 Taproots

Dry matter yield per chicory taproot was significantly ($P<0.00$) heavier under lax grazing treatments than hard grazing treatment (Figure 4.9 a). The short spelling time also reduced dry matter per chicory taproot (Figure 4.9 b).

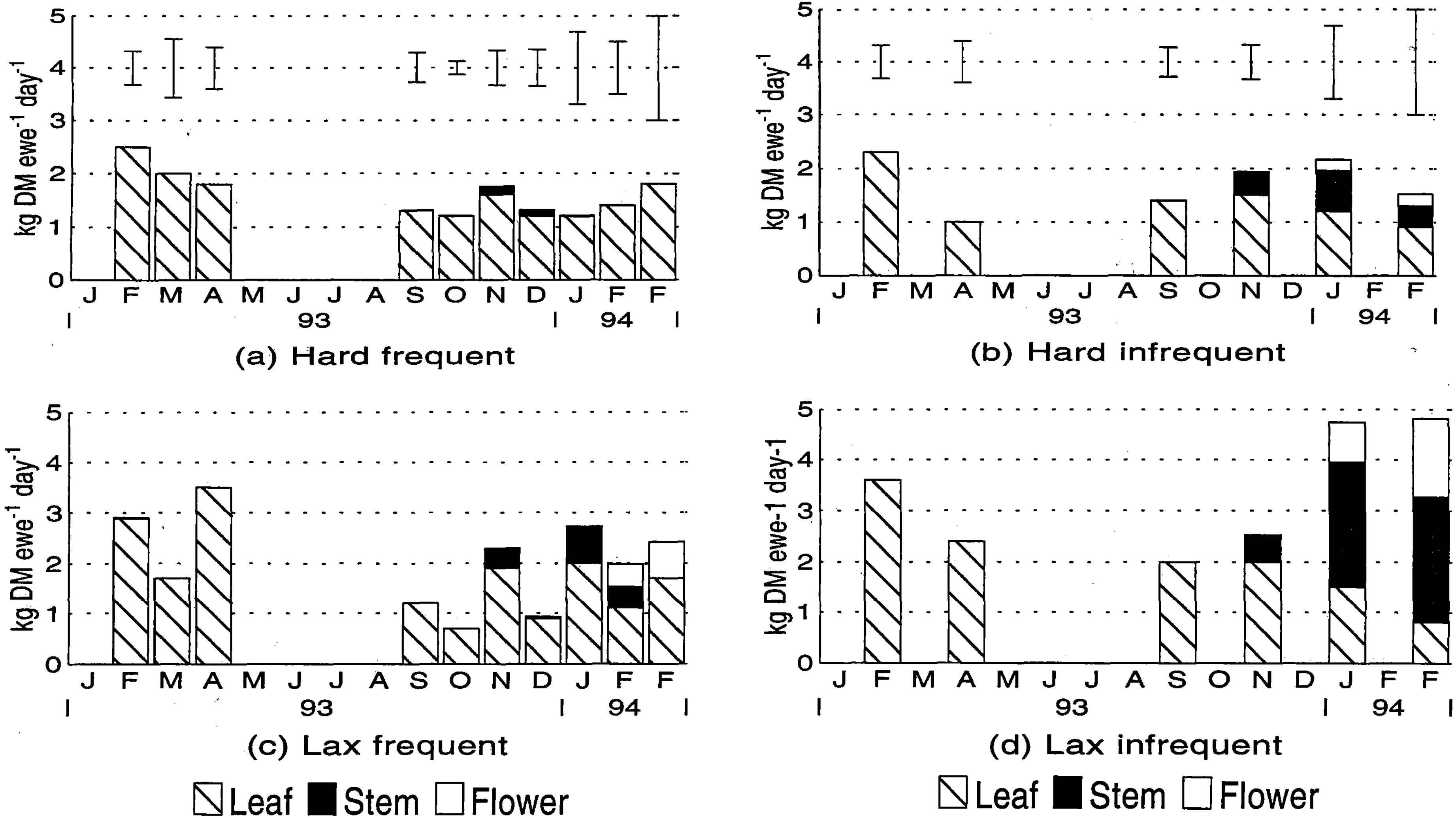


Figure 4.6 Daily rate of disappearance of chicory per ewe hogget in the grazing treatments (a, b, c, and d) according to chicory plant components (from 25 January 1993 to 26 February 1994). Error bars= SE_m

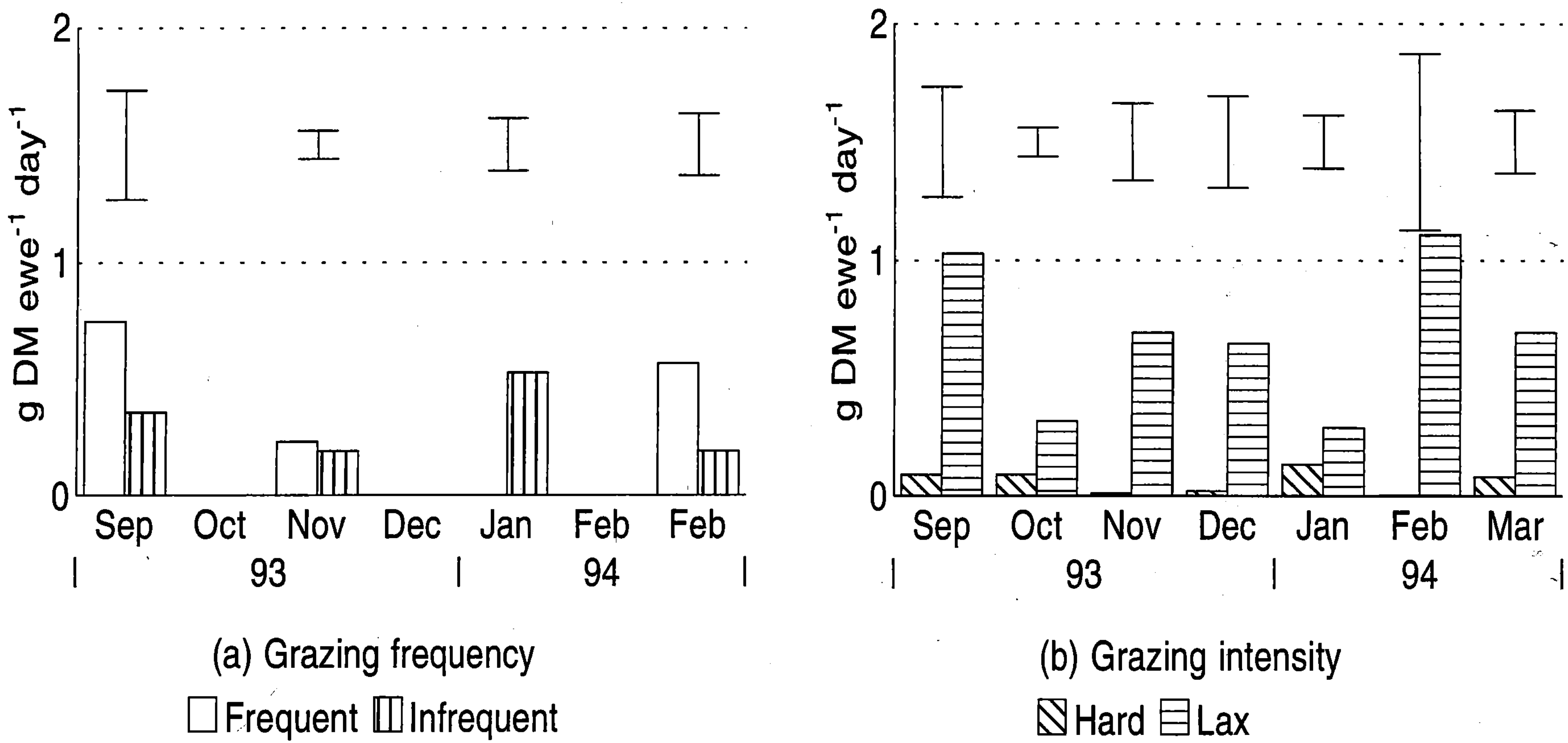


Figure 4.7 Daily rate of disappearance of white clover per ewe hogget at the main effects of grazing (a) frequency and (b) intensity treatments (from 16 September 1993 to 26 February 1994). Errors bar= SE_m

Plate 4.6. Chicory plants alive and dead (the latter due to in

Sclerotinia spp. Photo taken on replicate 4. Octo

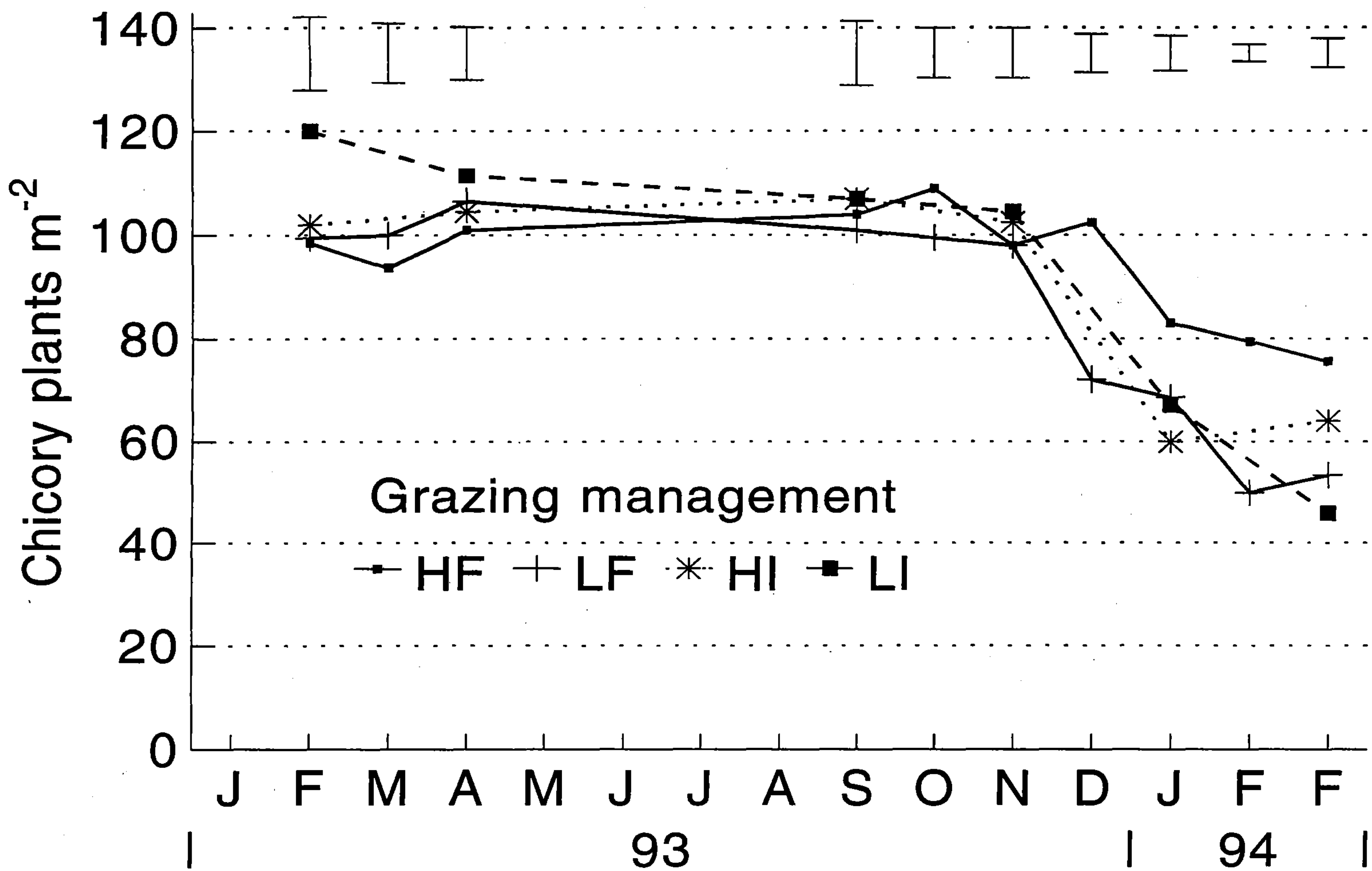


Figure 4.8 Trends of chicory plant populations at the grazing treatments from 25 January 1993 to 26 February. Error bars= SE_m

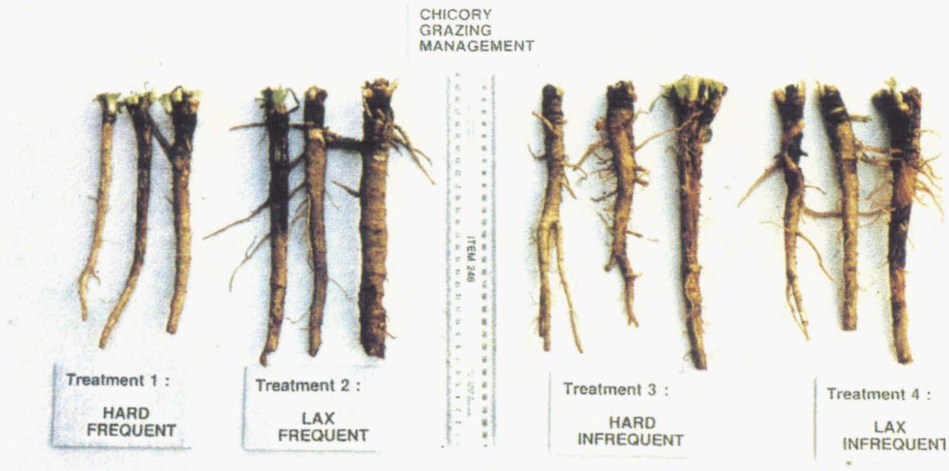


Plate 4.7. Size range of taproots for four grazing treatments (9 Marcl

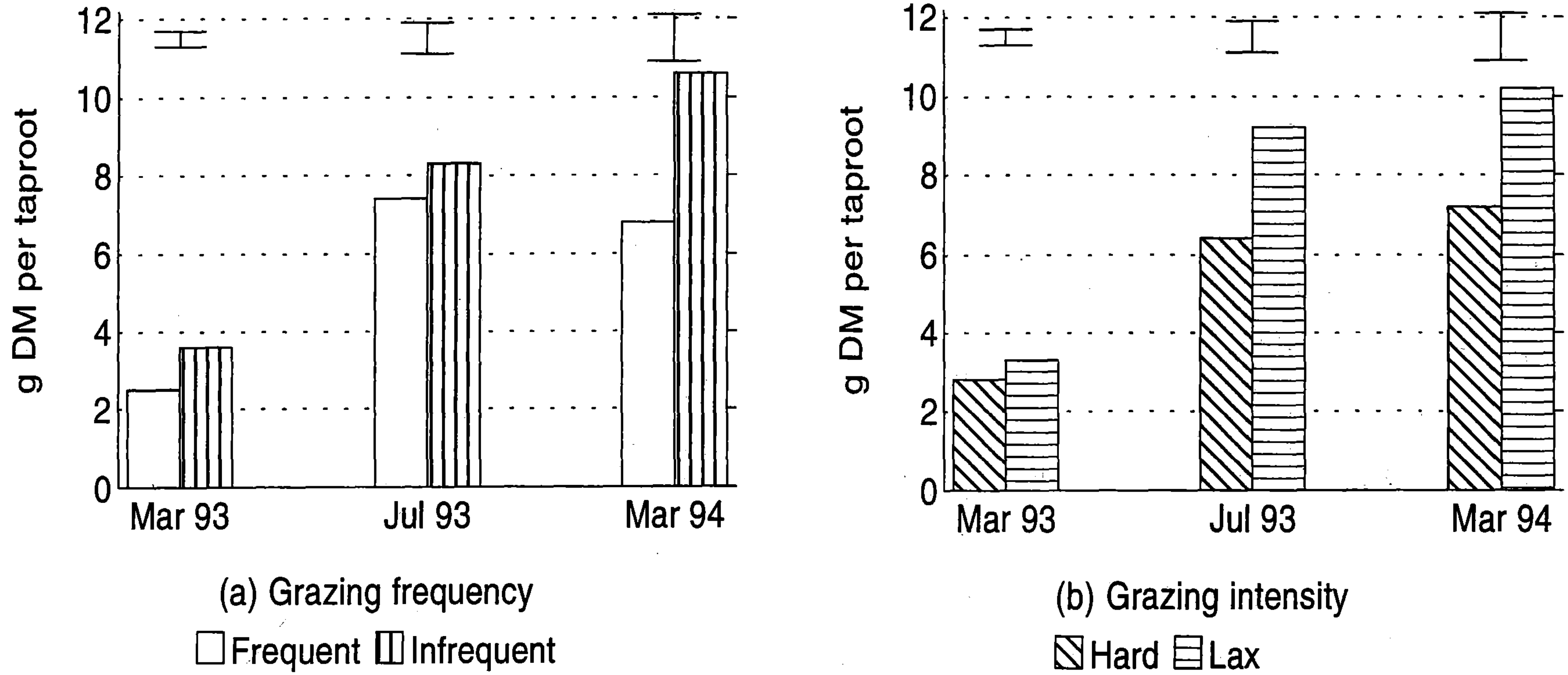


Figure 4.9 Dry matter yield per taproot from the main effects of (a) grazing frequency and (b) intensity treatments (March and July 1993 and March 1994). Error bars= SE_m

Hard grazing treatment reduced slightly the crown diameter per taproot when compared with the lax grazing treatment (Figure 4.10 a). However hard grazing treatment increased the number of crown buds per taproot by up to three crowns per taproot. The short spelling time also reduced crown diameter per taproot (Figure 4.10 b) and increased the number of buds per taproot by 2.5 per crown.

4.4 DISCUSSION

4.4.1 Effect of grazing management on chicory

4.4.1.1 Influence on herbage mass

Grazing intensity

Chicory is recommended to be laxly grazed. The main reason has been to avoid the accelerated decline of plant population. Clark *et al.* (1990) found that chicory production declined when cut to ground level, but they did not mention having a *Sclerotinia* problem. Matthews *et al.* (1990) also showed low production of chicory under hard grazing, but in spite of this they suggested that chicory should be heavily grazed to reduce the production of reproductive stems.

The current results have indicated that when chicory is heavily grazed the effects of *Sclerotinia* fungus may be reduced. It is possible that the hard grazed treatments resulted in lower crop humidity and a less favourable environment for *Sclerotinia*. The *Sclerotinia* fungus is likely to be present in most regions and it is likely that outbreaks can threaten the persistence of chicory stands more than usual during wet spring conditions (Hare *et al.* 1987).

After November grazing leaf dry matter yield was reduced because chicory plant directed more photosynthates into reproductive structures rather than leaf growth. This was more evident in lax grazing treatments. Moreover dry conditions also occurred which reduced leaf growth. This problem was mentioned by Matthews *et al.*

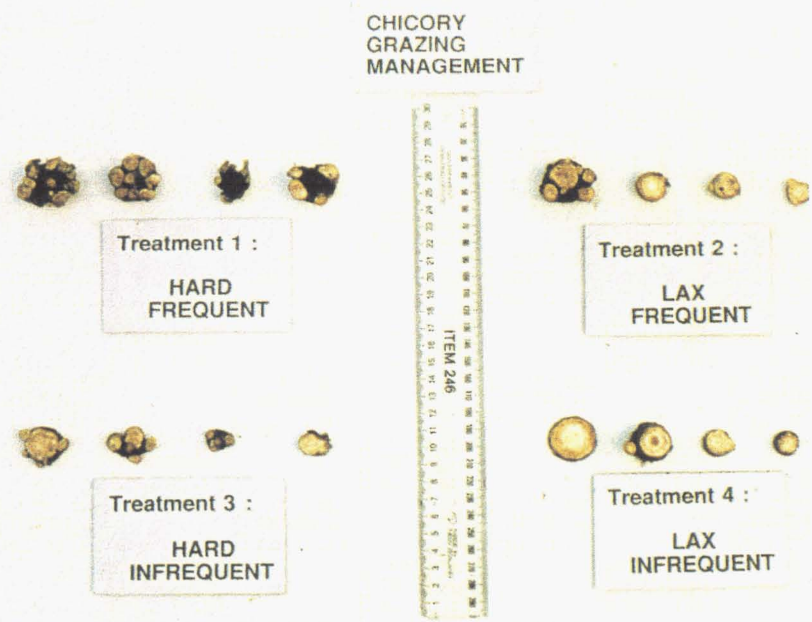


Plate 4.8. Cross section of a range of chicory taproot crowns sl number of buds per crown at the end of the experimei 1994).

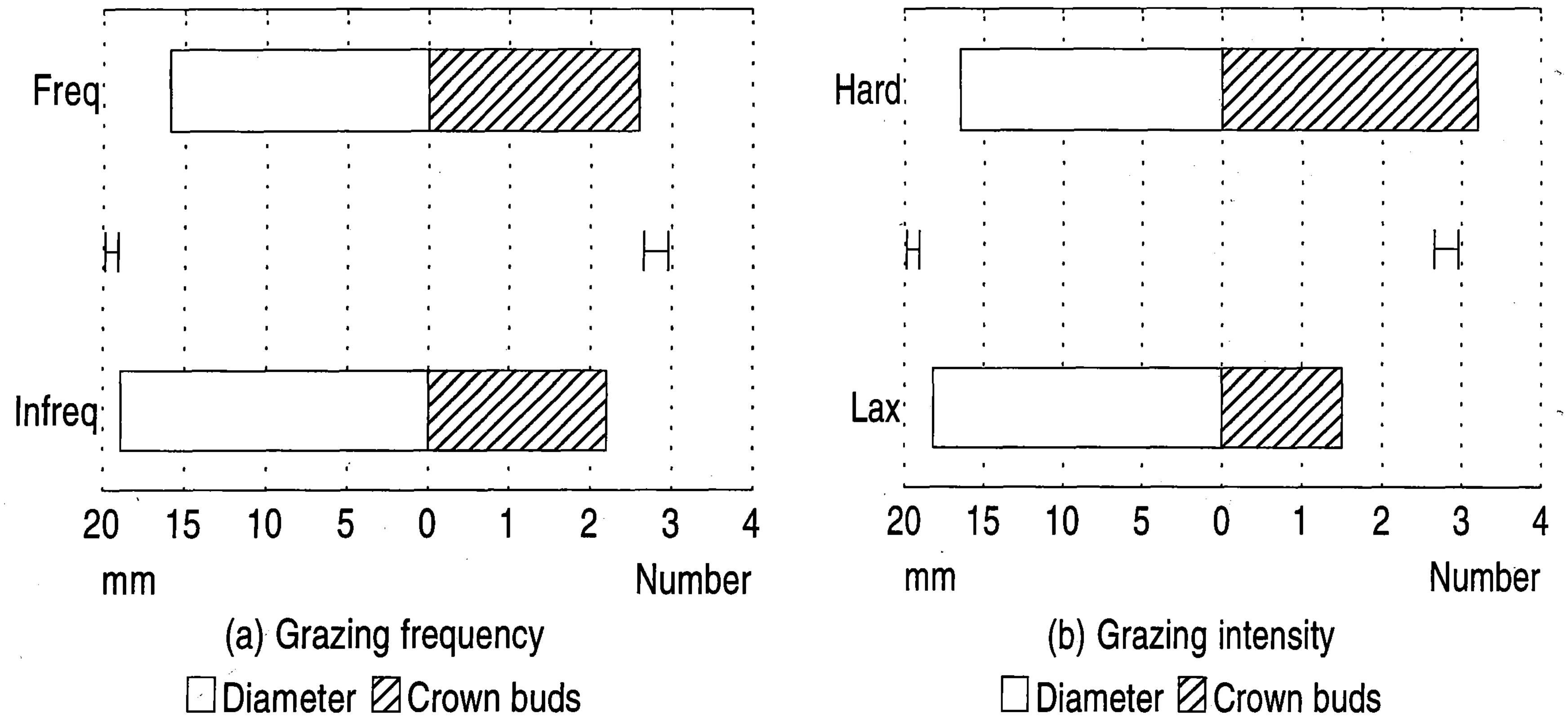


Figure 4.10 Mean crown diameter and number of crown buds per taproot from the main effects of grazing (a) frequency and (b) intensity treatments (9 March 1994). Error bars= SE_m

(1990) who indicated the adverse effect of moisture deficit on chicory yields in late spring. The onset of drought conditions should indicate to grazing managers the need for careful control of the intensity of grazing chicory.

The hard infrequent grazing seems to be a good management alternative to reduce the reproductive stem production and enhance leaf production. Therefore further research should be done to investigate hard grazing treatments with a range of spelling times. In addition the reduced dead matter production in the HI grazing shows that it may lead to more efficient use of herbage mass on offer. A contrary case is the lax grazing treatments where dead matter was an important component after chicory started to produce reproductive stems.

Grazing frequency

Grazing frequency decisions may be influenced by weather conditions, the assumed need to give time for taproot recovery and the need to control reproductive stems. A common practice is to avoid grazing when weather conditions are wet. Field observations from these experiments have indicated that ewe hoggests did not graze chicory during cold days or heavy rainfall in early spring (September 1993) and large amounts of leaf is wasted through trampling.

Long spells produce more dead matter and reproductive stems than the short spells. There were more stems dying off in the infrequent grazing treatments compared with the frequent treatments at the end of the trial. Therefore dead matter was increased when treatments were long spelled as in the LI grazing. However dead matter was decreased in the HI treatment because animals grazed the whole leaf production and some parts of stems.

4.4.1.2 Dynamics of chicory population under grazing

Chicory population followed a normal decreasing trend (Crawley, 1983). However it is difficult to determine if the grazing treatments or the *Sclerotinia spp* fungus reduced chicory populations. Two earlier papers indicated that chicory populations declined when it was heavily grazed (Matthews *et al.* 1990) or closely cut to ground level (Clark *et al.* 1990a). However a contrary effect occurred in the current trial. The current grazing treatments may have differently influenced microclimate conditions in the swards. It is assumed that hard grazing opened up the canopy allowing radiation to enter in the lower stratum. At the same time relative humidity is reduced by plants being shorter.

The outbreak of *Sclerotinia* spp. infecting chicory crowns started in September when there were temperatures from 4-13ºC and heavy rainfalls. Plant mortality appeared very severe in October when temperatures were a little higher and evapotranspiration exceeded rainfall. By November chicory plants were still dying off but to a lesser extent in the hard grazing treatments. It was not identified where the *Sclerotinia* fungus originated from into the swards. Hawthorne and Jarvis (1973) mentioned different sources of *Sclerotinia* dissemination such as ascopores, sclerotia or soil-borne mycelia. White clover has been identified as an alternate host of *Sclerotinia spp*, because some cultivars show susceptibility to that fungus (Watson, 1988) but there is some doubt about whether the *Sclerotinia* species attacking chicory is the same as that on white clover. The current white clover arose from buried seed of 'Grassland Huia', a susceptible cultivar.

4.4.1.3 Importance of chicory taproots

Chicory appears to rely on its taproot for regrowth. Frequent grazings reduced taproot size when chicory was heavily grazed. Chicory did not reduce its taproot yields when long spells were used. The HI treatment showed much better taproot production in terms of storing reserves and leaf DM production when compared with the lax grazing treatments or the HF treatment.

Comparing spelling times, taproots lose more reserves under frequent than under infrequent grazings. However this point needs to be studied over a longer term considering that taproot size did not show much difference when chicory was grazed under hard infrequent compared with those under the lax grazing treatments.

However grazing treatments produced a great difference in the crown bud number per taproot. Hard grazing greatly increased the crown bud number of chicory. Several points of growth increased the chance of having more points of regrowth. It may also be expected that the higher number of crown increased chicory persistence compared with nil buds under lax grazing. There is a need to find out of a close relationship between the increasing number of crown buds and chicory persistence under grazing in a long term.

4.4.2 Experimental difficulties in the current grazing trial

There were several factors which may have biased the results in the current trial. Mostly these were related to management of sheep, sampling intensity, dilemma of using total herbage mass or leaf production to achieve grazing protocol in the last grazings, and possibly the presence of new chicory seedlings.

The adjustment of sheep in each grazing treatment was a problem. Sheep number was reduced in the lax grazing treatments to achieve the grazing protocol a day early, then some sheep would be moved to achieve the hard grazing protocol. These management adjustments could change the amount of dung, urine and dung transferred to different grazing treatments.

Also moving sheep between treatment plots changed sociability of grazing animals. Sheep became upset or got lost within another group of ewe hoggets. This may persist for a whole day until the original grazers welcomed the new intruders. Usually this problem was partially solved by changing sheep during late afternoon. In any grazing cycle ewe hoggets were never starved, but they temporarily looked like that when a group of new animals was added into another grazing plot. That was because sheep initially rejected the partially grazed sward.

The low intensity of sampling (two 0.2 m^{-2} quadrats per grazing plot) was a difficult decision because there had to be a compromise between work load and increasing the number of samples to reduce the experimental error and to precisely estimate pre-grazing pasture mass on offer and residual post grazing DM. A higher number of samples per plot would have increased time required for both cutting and laboratory work. The two given sampling areas were selected with regard to grazing behaviour, avoiding border effects, and sampling representative samples. However the latter was affected by invasion of white clover and the outbreak of *Sclerotinia spp* which changed plant populations. Sampling positions were then changed to areas which were more typical.

In later grazing cycles low leaf production from the lax grazing treatments may have resulted in rapid leaf intake and, therefore, lax grazing could be equivalent to hard grazing treatment. This problem was anticipated and avoided in the ninth and tenth grazing cycles by acknowledging that residual leaf was the defined indication of grazing intensity.

A further problem related to carrying out this kind of small plot grazing experiment relates to the production of viable chicory seeds which may be dispersed into adjacent plots. High seed production from the LI treatment plots was evident in the last grazing cycle (February 1994). Mature plants were always counted, but there were seedlings emerging close to fences. In future young seedlings may establish in adjacent plots where the grazing treatments did not seed to set.

4.5 CONCLUSIONS

The hard infrequent grazing seems to be the best option for chicory management on sheep farms. The great dry matter yields of leaf and taproots and high number of chicory plants per metre square are two main reasons to support the latter point. Also it has been shown that hard grazing may be a way to reduce the outbreaks of *Sclerotinia spp.* Hard grazing also reduces number of primary reproductive stems. The greatest leaf production means the HI management provides most high quality feed for sheep. However, hard grazing is not compatible with high intake requirements of young growing sheep or lacting ewes. There is therefore a need when grazing chicory in summer to have a "leader/follower" grazing system. Animals such as weaned lambs which require high intakes of green leaf would graze first in the leader flock and animals such as dry ewes on maintenance rations would be in a follower flock to eat reproductive stems.

CHAPTER 5

GENERAL DISCUSSION

5.1 DETERMINATION OF CHICORY SOWING RATES

The objective of these experiments were to obtain data which would serve as a guide for the determination of chicory sowing rates when sown in pure swards or in mixtures with clovers (white clover or red clover) or winter-active grasses (prairie grass or phalaris).

Chicory grown under conditions similar to those experienced in the current work it is likely to demonstrate the same general patterns of growth. There is however no rule to indicate that any single sowing rate is best for a whole range of environments. Although there are several factors which may justify varying from a recommended seeding rate, most deviations would depend on seed-bed preparation, seed quality and sowing conditions.

Seed-bed preparation influences the ability of seeds to emerge out of the ground. Smaller seeds have greatest difficulty emerging when soil has been badly prepared. Soil was well-prepared in the current trials, but it is likely the smallest seeds (white clover and phalaris) were most affected by weed invasion.

Seed quality plays an important role in establishing pasture species because it enhances a good establishment of plant species in a sward. Archie *et al.* (1993) indicated that TSW and germination has a strong, positive correlation ($r=0.95^{**}$) in chicory seed; when TSW was 1.9 g seed germination was 90%. In the current experiment the TSW was 1.63±0.16 and germination declined down to 68%. The seed quality of chicory seed used by Fraser *et al.* (1988) in Southland and Kise *et al.* (1987) or Romero *et al.* (1988) in Argentina were not reported.

Weather conditions have an important influence on the initial establishment of germinating seeds. Mid- or late- spring sowings are more likely to suffer drought. In the current experiments water was not a limiting factor during seed germination because there was a short rainfall in the sowing day (30/11/93) which was enough to soak the soil and enhance water-uptake by chicory seeds. In November 1992 mean temperature was 13.8ºC varying from 9.2 (minimum) to 18.5ºC (maximum). Although temperature did not affect the sown seeds the late sowing probably increased weeds in the chicory plots. Weeds or volunteer plants suppressed chicory during the first two months. Therefore if chicory sowing is delayed until late in the growing season it may experience strong competition from weeds. An earlier sowing than November could favour chicory seedling establishment by avoiding some weed competition but colder temperatures in early spring could reduce germinating seedling vigour. Earlier sowing in September would allow seedlings to fully exploit warm summer growing conditions better than the early summer sowing time of the present experiments.

Two main points of discussion from these establishment experiments are sowing rate for pure swards and mixtures and the choice of companion species.

5.1.1 Pure chicory stands

Chicory showed strong intra-specific competition when sown in high plant populations. If nutrients, water or space are limited by growing plants then the weakest seedlings or plants will not survive. Chicory had greatest population decline at high sowing rates and more reproductive stems in low sowing rates.

Taproot size was smaller in high sowing rates. The greater weight of individual taproots at low populations indicated that the key point of chicory growth may be in the development of its taproot. If there is a close relationship between stored carbohydrates for regrowth and dry matter per taproot then the importance of large taproots for successful grazing of chicory should be emphasized. That means chicory plants with large taproots could have longer persistence than plants with small taproots. This point should be looked at in a future experiment because a small taproot may also be at a disadvantage for overwintering (Hare *et al.* 1987).

5.1.2 Pasture mixtures

The best mixture will be the one which fills the feed demand of grazing animals both in quantity and quality on a year round basis. This is not always achieved because the best mixture may be affected by a given pasture management and its persistence may also be limited.

Chicory suppressed companion species when sown at seeding rates higher than 1.5 kg/ha especially during the warmer season when chicory produced tall reproductive stems. This shows that companion species cannot survive within the chicory pasture if these are slow establishing plant species (white clover or phalaris) and if chicory grows vigorously. Grazing management of chicory should be controlled early in spring to allow companion species to successfully compete. Similar early grazing may be necessary at early stages of chicory establishment to allow companion species to survive strong competition for light by chicory. The three month spring growing period without defoliation in the current research was too long and the smothering effect of tall reproductive chicory was very evident. Spring defoliation should have been at about 3 to 4 week intervals to encourage the shorter species and to suppress chicory reproductive growth.

Between the two clovers, white clover could be the best alternative because of its ability to spread by stolons to occupy bare spaces, but its slow establishment and low yields in this study were disappointing. White clover grew unsuccessfully because chicory and weeds were much more competitive. The larger seeded red clover had much better performance than white clover but in mixtures with chicory the pasture may be short lived because both species have been found to be susceptible to different species of *Sclerotinia spp* (Hare *et al.*, 1987; Ledgard *et al*, 1992). However the chicory/red clover mixture can fill the animal demand in the short term for very high quality summer feed. This mixture may disappear after three or four years, but it is likely to be very productive in the warmer months.

Grasses showed widely different responses when sown in mixtures with chicory. 'Matua' prairie grass had much higher yields than 'Maru' phalaris in all mixtures. 'Maru' phalaris was very slow establishing and it did not compete well in long spells between cuttings. Therefore chicory suppressed 'Maru' phalaris which declined in yield when chicory dominated the plots. Winter should normally be a good period for well established 'Maru' phalaris to complement the dormant chicory and white clover in the cool season, but its early vigour in the first winter was disappointing.

'Matua' prairie grass grew successfully in the first winter at low chicory sowing rates, but it was suppressed by chicory at sowing rates higher than 3 kg/ha during spring. In the latter case both chicory and prairie grass plants showed fewer reproductive stems when compared with lower sowing rate plants. The normal productive life of 'Matua' prairie grass of three to four years is relatively short and similar to expectations for red clover and chicory. These three species are therefore likely to be a good combination for a short term high quality pasture.

Lastly, chicory is a very dominant pasture herb at high plant populations showing strong intra- and inter-specific competition when it is infrequently grazed. Red clover had much better performance than white clover in these one year experiments, but there is no conclusive support for it. 'Matua' prairie grass was much more productive than 'Maru' phalaris in the establishment year, but it is likely that phalaris will have greater production in the second year. If sufficient white clover and phalaris plants survive the first year then their increasing vigour over time may result in a productive perennial pasture once chicory populations decline.

5.2 GRAZING MANAGEMENT OF CHICORY

The objective of the grazing trial was to investigate the response of chicory to defoliation by grazing sheep. Questions were related to: (1) whether chicory needs residual leaf to recover rapidly and have maximum productivity after grazing and (2) how grazing management would affect chicory persistence. Therefore two grazing frequencies (F= short and I= long spells) and two grazing intensities (H= hard and L= lax) produced four grazing treatments (HF, LF, HI and LI) which were used to answer those questions.

Grazing management involves several decision making steps. These should be related to weather conditions, pasture mass on offer, reproductive development stage of the pasture and requirements of the livestock and their grazing preferences.

Animals have wide differences in feeding demand and preferences for pastures species . Sheep are selective for leaf tips and softer plant structures (Arnold, 1981). In controlled experiments grazing behaviour can be changed by increasing the number of animals in a paddock. For instance hard grazing reduces animal selectivity and, therefore, it can reduce reproductive stems. However hard grazing may reduce and restrict animals' weight gain. In the current experiment sheep grazed heavily the reproductive stems in the frequent grazing treatments during early spring. However high fibre content and possibly the bitter taste of stems reduced animal grazing of stems after November. When chicory was produced less leaf after November grazing sheep preferred to graze white clover plants rather than chicory stems.

The sward structure can be changed by grazing management. Therefore high quality feed can be produced by means of hard grazing and reducing the appearance of reproductive stems in contrast to infrequent or lax grazing. Matthews *et al.* (1990) suggested that hard grazing could change the chicory sward structure by reducing the reproductive stems in early spring. However there is no information to define when hard grazing is really hard. The current results and Matthews *et al.* (1990) and Guangdi *et al.* (1994) suggest that spring management of chicory should be directed to reduce production of primary reproductive stems.

By changing the grazing management with regard to weather conditions chicory plants should persist longer rather than when chicory is managed under only one rigid grazing regime. The general aims should be to avoid grazing chicory in very wet conditions or when crown buds are producing very short regrowth in drought conditions. Chicory therefore needs to be frequently grazed either hard or lax depending on temperature or soil moisture.

Some tentative suggestions for flexible grazing management strategies for chicory are as follows:

(1) Chicory swards should be grazed hard or lax in short spells depending on whether spring is dry or wet. Crown damage and wasted leaves result if chicory is heavily grazed during muddy conditions.

(2) In a dry summer chicory should be laxly grazed with long spells to avoid new growth damage and reduction in production before the next grazing. This suggestion is also supported by Matthews *et al.* (1990).

(3) The arguable point is whether chicory should be heavily grazed or not later on in autumn to avoid wasting leaves to winter frost. Whether or not chicory needs some residual leaf to produce photosyntates to accumulate in taproots for overwintering should be further investigated by lax and hard grazing during autumn. Infrequent grazing in autumn may also help increase taproot reserves for winter survival and subsequent spring vigour.

These grazing strategies imply that in general chicory is a relatively versatile pasture herb which can tolerate different grazing managements so long as the plant is spelled between grazings.

5.3 CONCLUSIONS

The most important findings and management strategies developed are :

1. Chicory can be sown at moderate seeding rates 1-3 kg/ha. The lower sowing rate should be used for mixtures with slow establishing plant species.

2. Clovers can be established with chicory when chicory is sown at low rates and weed and chicory growth is controlled by careful early grazing.

3. Winter active grasses can compensate for chicory cold season dormancy and help fill the pasture yield demand in early spring, but further work should look at long-term sociability of chicory and grasses and when winter grown grass should be grazed relative to chicory spring growth patterns.

4. Hard frequent grazing resulted in suppression of stem production, a high proportion of leaf, and greatest plant population.

5. Lax frequent grazing appeared to encourage adventive white clover, suppress primary stems but did not control secondary reproductive stems.

6. Hard infrequent grazing resulted in large taprooted chicory plants, a balanced leaf:stem proportion, and high plant population.

7. Lax infrequent grazing resulted in excessive amounts of primary reproductive stem development, seed production, only moderate amounts of leaf yield, and low plant population.

8. Population of chicory declines with outbreaks of *Sclerotinia* fungus, but hard grazing may reduce its impact.

5.4 FURTHER RESEARCH WORK WHICH SHOULD BE UNDERTAKEN:

1. Investigate the optimum chicory canopy height and density for first grazing after sowing. This is important to control weed invasion and avoid smothering of companion species by chicory or weeds.

2. Investigate the critical period for control of developing reproductive stems during spring grazing especially in September and October.

3. Long term trial to find the persistence of chicory under hard grazing at different spelling times (3, 4, 5 or 6 weeks) and its impact on reducing the adverse effect of *Sclerotinia spp.*

4. Monitor the effect of autumn management on the development of taproot size and storage of total non-structural carbohydrates in relation to persistence of chicory.

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