The effect of grazing intensity and frequency during spring and early summer on the sward characteristics of a ryegrass-white clover pasture

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ABSTRACT

The effect of grazing intensity (to approximately 150 (H), 450 (M) and >750 (L) kg lamina DM/ha at a 14 day rotation length, i.e. H14, M14 and L14) and grazing frequency (at 7, 14, 21 and 28 day rotation lengths at the M level of intensity, i.e. M7, M14, M21 and M28) on the sward characteristics of a perennial ryegrass-white clover sward was examined over 24 weeks in spring, summer and early autumn.

The grazing treatments were imposed over a 12 week (treatment) period (mid-Sept to mid-Dec) in spring and early summer to determine a) whether or not pasture 'control' (or some intermediate state) resulted and b) why differences between managements arose. It was found that treatments H14, M7 and M14 could be considered 'controlled' but treatments L14, M21 and M28 could not. This was largely because in the latter, the proportion and mass of ryegrass reproductive stubble, green and total herbage masses, sward height and emerged inflorescence density were much greater; and Leaf:Stem ratio, tiller density and lamina accumulation were much lower, than in the former. The individual mass of reproductive tillers was the most important factor determining differences in ryegrass reproductive stubble mass, rather than reproductive tiller density.

Over the following 12 week (post-treatment) period (mid-Dec to early-Mar) subsequent pasture production on these swards was measured under a common grazing regime. It was concluded that a greater 'risk' of poor lamina accumulation was associated with lack of pasture 'control' and this was largely influenced by the recovery of tiller density. During this period ryegrass reproductive stubble died and 'uncontrolled' swards had higher herbage mass due to a greater mass of dead herbage.

The proportion of white clover in herbage mass and lamina accumulation was greater on M7 swards during the treatment period and on both M7 and H14 swards during the post-treatment period.

In practice, herbage mass and sward height probably the best criteria on which to base spring grazing decisions because both are highly correlated with individual ryegrass reproductive tiller mass. Pasture 'control' may be maintained on a ryegrass-white clover sward by grazing to a sward by grazing to a sward height of 6-9 cm (1400-1600 kg green DM/ha) from a pregrazing sward height of less than 20 cm (2700-3000 kg green DM/ha).

Key Words perennial ryegrass, white clover, grazing intensity, grazing frequency, sward characteristics, pasture 'control'

CHAPTER 1 INTRODUCTION

The objective of grazing management in spring and summer is to obtain high feed intakes of stock so that per hectare performance and income is optimized.

With the increase in temperature and solar radiation, and the change from vegetative to reproductive growth in grass species, net herbage production over spring increases dramatically. Because net herbage production in mid- to late spring is most often very much greater than that required by grazing stock large feed surpluses often occur. Much of that surplus is grass reproductive stubble which, is not removed, dies over the summer months. The accumulation of reproductive herbage over the late spring and summer has been shown to lead to poorer pasture quality (Smetham 1973, Korte 1981), stock performance (Lewis and Cullen 1964,1974, Smeaton 1983, Hughes 1983) and lower subsequent net herbage accumulation (Korte 1981, Sheath et al 1984). Therefore, management to 'control' late spring pasture surpluses has been advocated as a key element in acheiving farm performance objectives (Sheath and Bircham 1983, Sheath and Bryant 1984, Smeaton 1983).

The results of 'pasture control' on sward characteristics and performance has been described (Korte 1981, Sheath and Bircham 1983, Sheath and Bryant 1984, Sheath et al 1984, Holmes and McClenaghan 1979, Holmes and Hoogendorn 1983). A 'controlled' pasture is composed of high quality, dense, leafy herbage with a relatively high clover content, and high subsequent net herbage accumulation. An 'uncontrolled' pasture is one in which the herbage is poor quality, stemmy and rank, with a large content of dead herbage and poor content of clover. Low tiller density may lead to poor subsequent herbage accumulation especially in dry summer conditions.

In research and discussion papers on late spring grazing management the differences between 'controlled' and 'uncontrolled' pasture has often been described in the somewhat vague descriptive terms used above, especially with regard to the pasture quality aspects (for example, 'leafy', 'stemmy', 'rank'). Greater definition of these pasture conditions in terms of specific pasture measurements is required.

The treatments compared by Korte (1981) were at the extremes of the range of management options (e.g. hard versus lax). The resultant pastures could be easily classified as 'controlled' or 'uncontrolled'. Korte (1981) recognised that further work was required 'to establish how stemmy swards can become before the advantages of leafy swards are lost'. It is not known whether different late spring management (including intermediate frequency and intensity) would create a gradation of sward conditions so that pastures lie between those easily classified as 'controlled' or 'uncontrolled', or whether there is a threshold or critical management regime which, when exceeded, causes a rapid change between the two states. Whichever is the case there is a need to establish a) the critical measurements that indicate the pasture status as 'controlled', 'uncontrolled' or somewhere inbetween, and b) the critical value or range of values within each measurement that clearly show the pasture status. It may be that a combination of measurements best describes the pasture status in which case this combination needs to be identified. The trial reported in this thesis was designed to investigate the questions raised above. The treatments therefore included both hard and lax grazing because, from previous research these would result in 'controlled' and 'uncontrolled' swards respectively. The main emphasis, however, was on a moderate graing intensity at a level which might give 80-90% of maximum intake in lactating ewes (as indicated by pasture allowance trial results (Rattray et al 1982)). As it is known that the length of spell between grazings may influence the level of 'control' acheived (Sheath et al 1984, Hughes 1983), a range of grazing frequency was included at the moderate grazing intensity. Thus treatments resulted in two distinct grazing frequency and intensity comparisons.

The grazing trial was conducted with sheep on high fertility ryegrass/ white clover swards over the spring and summer with the following specific objectives.

1. measure changes in sward characteristics and herbage accumulation to identify whether or not pasture 'control' (or some intermediate state) resulted from the managements imposed.

2. identify and quantify the major determinants of differences between the swards.

3. measure the subsequent pasture productivity of the spring grazing treatments under common management during summer and early autumn and identify the factors most influencing productivity.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

Animal production in New Zealand and in many other countries is largely based on temperate pastures. Considerable research has been done to elucidate the responses of pastures to management especially with respect to the intensity and frequency of defoliation.

This review will outline pasture responses to defoliation in terms of changes in herbage mass and other sward characteristics, and herbage accumulation. Emphasis will be given to the response of individual pasture components (especially leaf lamina) to defoliation and to the underlying physiological factors determining these responses particularly on predominantly ryegrass/ white clover swards and during the spring and summer periods.

2.2 EFFECT OF DEFOLIATION ON HERBAGE ACCUMULATION

2.2.1 TOTAL HERBAGE ACCUMULATION

Control over the frequency and severity of defoliation has long been advocated as a means by which the productivity of pastures can be increased (Jones 1933a,b, Smetham 1975, Smith and Dawson 1976, Milligan 1981, Holmes 1980).

It is generally concluded that increasing the frequency of defoliation reduces herbage production from a ryegrass/clover sward (Brougham 1959b, Appadurai and Holmes 1964, Agyre and Watkin 1967, Boswell 1977) though there are examples of increased herbage production (Davidson 1969). Very infrequent defoliation may also reduce herbage production (Bartholomew and Chestnutt 1977). Brougham (1970) showed that grazing too infrequently in the winter (126 days versus 42 days) reduced yeilds by 40%. A similar reduction was noted by Baars et at (1981) when winter pastures were grazed at 4000 kgDM/ha rather than 3000 kgDM/ha. In a review of grazing experiments Hodgson and Wade (1978) concluded that defoliation at intervals less than 2 weeks may reduce net herbage accumulation by up to 40%. Grazing every 4 weeks consistently increased production 15-17% over 2-3 weekly grazing when the height of grazing was controlled.

The response of cut swards to defoliation intensity is inconsistent (Davidson 1969). Hodgson and Wade (1978) concluded that the effect of defoliation intensity on annual yeilds was small in most trials. However, Brougham (1955, 1956, 1959b) and many others (Hunt 1970, 1971, Green et al 1971, Leafe et al 1974, Wilman et al 1976d) have shown that herbage growth after severe defoliation is sigmoidal over time. Three distinct phases are recognised: an exponential phase- when growth rate increases exponentially with time; then a linear phase- during which growth rate is at a maximum; followed by a third phase in which growth rate declines until ceiling herbage mass is reached. Bircham (1981) and Bircham and Hodgson (1983 a,b) also clearly showed that net herbage production is reduced by severe continuous stocking (below 700 kgDM/ha). Above this level there was little difference in net production over a wide range of herbage mass (up to 2000 kgDM/ha).

Comparisons between trials are very difficult because of the diverse range of environment, management (e.g. variation between severities of hard grazing), and measurement technique. Inconsistencies in results may be due to interactions between defoliation frequency and intensity. For example, Brougham (1959b) showed that annual yeilds were reduced 20% by frequent severe grazing (7.5 cm to 2.5 cm versus 17.5 cm to 7.5 cm). However if grazing frequency was reduced (i.e. 22.5 cm to 2.5 cm versus 7.5 cm to 2.5 cm) then no reduction in herbage accumulation eventuated. A common explanation of these results is that less frequent hard grazing enables pastures greater time in the linear phase of growth so that net production is not reduced. However very similar results were obtained by Brougham (1960) during the spring when there may be little or no exponential phase to the growth curve (Brougham 1959a, Brougham and Glenday 1969). Korte (1981) also found during spring that herbage mass appeared to increase almost linearly between grazing (either hard or lax) and 95% light interception.

Inconsistencies in results may also be due to previous management, soil type, type of defoliation, moisture status , stage of growth and botanical composition.

Brougham (1960) found infrequent hard grazing in winter outyeilded lax grazing but Tainton (1974b) showed that alternate lax and hard grazing in autumn may outyeild hard grazing by 63%. Baars et al (1981), however, found only a small increase (10%) when previously hard grazed swards were laxly grazed and 12% lower production when hard grazing previously lax grazed swards. Bircham and Hodgson (1984) also found that changing the intensity of grazing from lax to hard under continuous grazing reduced herbage accumulation but it did not increase when changing from hard to lax grazing.

Baars et al (1981) found differences between peat and clay soils in their responses to grazing and this was attributed to the different botanical composition of the swards- the peat being of higher clover content than the clay. Sheath and Boom (1985) found that hard summer grazing did not lower herbage accumulation as did Brougham

(1960, 1970), and attributed this to pastures of predominately annual species rather than the ryegrass based pastures of Brougham, despite similar moisture status. Brougham (1960, 1970) and Tainton (1974a) found that herbage accumulation was reduced (40% and 20% respectively) by hard than lax grazing during dry summers. Appadurai and Holmes (1964), however, found that when the soil was maintained close to field capacity ryegrass/white clover pastures produced 20-41% more under hard (2.5cm) than lax (7 cm) cutting.

Peak accumulation rates within a year coincide with ryegrass inflorescence emergence (Anslow 1965, Anslow and Green 1967, Langer 1959, Silsbury 1965, Alberda and Sima 1968, Leafe et al 1974). In New Zealand 60-80% of annual growth usually occurs during spring and early summer (Rattray 1978).

It appears that the effect of defoliation frequency is much greater under cutting than grazing (Hodgson and Wade 1978), especially with reproductive swards (Bartholomew and Chestnutt 1977, Chestnutt et al 1977, Korte 1981). Wilman et al (1976a,c), Mislevy et al (1977), Corrall (1974) and Gillet (1973) have all found that annual herbage production was reduced 20-40% when reproductive development was interrupted at a leafy stage compared to interruption at anthesis.

Lax rather than hard grazing may increase (Carton and Brereton 1983), decrease (Binnie et al 1980, Holmes and McClenaghan 1979, Holmes and Hoogendorn 1983) or have no effect (Korte et at 1982b, 1984) on total spring herbage accumulation. Such differences may be due to an interaction between defoliation frequency and intensity, and climatic conditions.

Spring management may also affect subsequent herbage accumulation. Pastures that are lax rather than hard grazed during spring may have substantially reduced total accumulation during subsequent periods (Korte et al 1982b, 1984, Sheath et al 1984, Sheath and Bircham 1983, Holmes and McClenaghan 1979, Holmes and Hoogendorn 1983). Korte (1981) and Holmes and McClenaghan (1979) found that herbage accumulation from swards laxly grazed in spring was rapid under moist summer conditions but not under dry. Longer periods of moisture stress may result in the effects of lax spring grazing appearing later. For example, Sheath and Bircham (1983) found that when adequate rewetting did not occur until May, winter and spring animal performance was reduced on swards which were laxly grazed during the previous spring.

There is little direct evidence to suggest that infrequent grazing during the spring will result in lower subsequent accumulation but as the effects of infrequent grazing are similar to lax grazing then lower subsequent accumulation might also be expected. Sheath and Bircham (1983) however, have shown that lower accumulation may result after the hard grazing of previously infrequently grazed swards.

2.2.2 COMPONENTS OF NET HERBAGE ACCUMULATION

The net herbage accumulation (NHA) of a grazed sward is a function of several sward processes: growth (G), death and decay (D) and animal consumption (C) (Wade 1975, Davies 1981, Bircham 1981). That is,

$$NHA = G - (D + C)$$

In an established ryegrass sward each tiller bears an average of approximately three leaves (Davies 1977) and leaves are constantly appearing and dying, thereby maintaining this number. Whole tillers too, are forming or dying depending on sward conditions. The objective of management is two-fold: to maximise production of harvestable herbage and the secondly to utilise that production as well as possible because herbage that is not harvested will eventually senesce and die (Wade 1975).

The balance between herbage growth and death can result in similar net herbage accumulation under a wide range of management (Parsons et al 1983a,b, Bircham 1981, Grant et al 1983, Hodgson et al 1981). For example, Bircham (1981) showed that under continuous grazing compensating changes in the rates of herbage growth and senescence mean that net herbage production is relatively constant over a wide range of herbage mass (1000 to 2500 kg OM/ha), sward surface height (2-8cm) or leaf area index (LAI from 1.0 to 4.5). At the lower extreme (<1000 kgOM/ha) herbage growth restricted net production and at the higher extreme rates of senescence would reduce net production.

This balance is also seen in studies comparing continuous stocking and rotational grazing. There have been advocates of both continuous stocking (e.g. McMeekan 1960) and rotational grazing (e.g. Smetham 1973, Smith and Dawson 1976) who have based much of their argument on aspects of herbage production. Trials designed to investigate differences in annual production have failed to show consistent results (Arnold 1969, Marsh 1976, Clark et al 1982). Rates of photosynthesis under rotational grazing are either similar to those under continuous stocking or higher (King et al 1984, Deinum et al 1983, Parsons et al 1983c) depending on defoliation severity and frequency. This need not lead to higher animal production under rotational grazing because of higher rates of senescence (Parsons et al 1983c, Deinum et al 1983).

Although death and decay of herbage are one function in the NHA equation the two processes occur at different rates and are influenced by different factors. Therefore considerable dead herbage may accumulate in the sward (see section 2.3). Inclusion of dead herbage in net herbage accumulation may seriously alter the magnitude and interpretation of experimental results (McCree and Troughton 1966, Baars et al 1981).

Total herbage accumulation is a result of the proportions and accumulations of the different pasture species, and component parts of those species (i.e. leaf lamina, leaf sheath, reproductive stem and inflorescence, and dead). Because of the different accumulation rates of these components within, and between, seasons, the effect of management on herbage accumulation when expressed in terms of total, green, or leaf lamina accumulation are likely to be completely different (Wilman et al 1976a,b,c,d, Korte 1981, Carton and Brereton 1983, Bircham 1981).

Carton and Brereton (1983) state that 'the analysis of grazing management effects in terms of total dry matter production is of limited value because no account is taken of the effects of management on the feed value of the dry matter produced'. Carton and Brereton (1983) suggest the use of lamina rather than total accumulation as a measure of sward productivity and Bircham (1981) has proposed that management decisions should be based on the level, and changes to the level, of lamina mass.

In this respect differences between vegetative and reproductive pastures may be very large and are of considerable importance. In vegetative pastures the proportion of lamina and stubble in green herbage accumulation appears to be reasonably constant. Johnson and Thornley (1983) from the data of Robson (1973) calculated that the proportion of lamina in regrowth from severe defoliation was 0.70.

In reproductive pastures the proportion of lamina in net green herbage accumulation may fall well below this level depending on defoliation management. Brougham (1956) defoliated pastures to 2.5, 7.5 and 12.5 cm and measured regrowth over 32 days. It was found that total herbage yeilds were 18% and 26% higher when pastures were cut to 7.5 and 12.5 cm respectively. However, calculations on the data of Brougham (1956) show that the increment in Leaf Area Index relative to 2.5 cm cutting was 0.84 and 0.43 in the 7.5 and 12.5 cm cuts respectively. This indicates that the proportion of lamina in net herbage accumulation was much lower with less severe grazing.

More direct evidence however comes from the trials of

Tainton (1974a), Korte (1981), Carton and Brereton (1983) and Wilman et al (1976a,c). Tainton (1974a) found that, over October and November, leaf growth was dominant over stem and sheath growth during the first three weeks following severe (2.5 cm) grazing, after which leaf growth rapidly declined and sheath and stem growth was dominant. Very similar results were obtained by Wilman et al (1976a,c) who found that the proportion of lamina in the sward declined from 80% to 5% during stem elongation as a result of both a decline in lamina mass and an increase in stubble mass.

Although Korte (1981) found no difference in total herbage accumulation between hard and lax grazing, lamina accumulation was much greater with the former. Carton and Brereton (1983) grazed pastures at heights of less than 5 cm or 5-8cm at 21 day intervals and found that although total herbage accumulation was 21% higher under lenient grazing there were no significant differences in lamina accumulation.

Korte (1981) also found that spring grazing can influence lamina accumulation over summer. Lamina accumulation was significantly reduced by frequent (grazed at 95% light interception) but not infrequent (grazed at 2 weeks after 95% light interception) lax spring grazing compared with hard grazing over the spring.

A very large proportion of herbage accumulation in reproductive swards may be reproductive stem rather than lamina. The greater accumulation of reproductive stem and dead herbage with infrequent and/or lax defoliation (Korte 1981, Wilman et al 1976d) remains largely uneaten by the grazing animal (Korte 1982). Reproductive stem subsequently dies over summer and total and green herbage accumulation may be dramatically altered by the death and decay of reproductive stubble over the summer and autumn (Korte 1981,1982).

2.2.3 FACTORS INFLUENCING THE GROWTH, DEATH AND DISAPPEARANCE OF HERBAGE

For reasons discussed in the previous section the factors influencing lamina accumulation will be concentrated on in this section.

2.2.3.1 LAMINA GROWTH

Sward lamina growth per unit area is a function of the tiller density, rates of tiller appearance and death, and the rate of leaf production per tiller which is a function of the rates of leaf appearance and leaf extension (Davies 1981).

2.2.3.1.1 Photosynthesis

Approximately 90% of the plant dry weight consists of organic compounds based on carbons fixed as CO_2 in photosynthesis. Respiration accounts for the loss of about half of the CO_2 fixed in photosynthesis but is essential for synthesis and maintenance of live tissue (Parsons 1981).

As the growth of above ground (or shoot) material only is potentially available to the grazing animal, partitioning of assimilates between shoot and root production may also be of importance. There is evidence that this is so in spring when the proportion of assimilates to the roots decreases at the time of reproductive stem elongation (Ryle 1970, Parsons and Robson 1981).

Leaf area index (LAI) is a measure of the photosynthetically active tissue in a sward (Robson and Sheehy 1981). Leaf sheaths and clover stolons are also photosynthetically active but they contribute very little (<5%) to the gross photosynthesis of the sward (Parsons et al 1983a,b, Korte and Parsons 1984). The green inflorescence is also very active photosynthetically (Ong and Marshall 1975, Ong et al 1978a) but its contribution to growth is not known.

Canopy photosynthesis is largely determined by LAI, light intensity, temperature and moisture stress (Sheehy et al 1979, Leafe et al 1977). However, other factors such as leaf age, canopy structure and stage of growth may have a significant influence on the rate of photosynthesis.

The youngest expanding leaves have the highest photosynthetic potential and the oldest the lowest (Woledge 1979). Therefore the proportion of leaves of different ages (Davidson et al 1981, Woledge and Leafe 1976) and also the position of these within the canopy (Sheehy and Peacock 1977) can also influence photosynthetic output. A more important factor contributing to the progressive decline in photosynthetic output of spelled or laxly grazed swards is the decline (especially in vegetative swards) in the photosynthetic potential of the youngest expanding leaves (Davidson et al 1981, Sheehy 1977, Woledge 1973, Woledge and Leafe 1976). This is a consequence of changes in the light environment of the developing leaf (Woledge 1977, 1978, 1979). In contrast, white clover shows little reduction in photosynthetic capacity as a result of shading during development, as successive petioles are larger and carry the leaf to the sward surface (Dennis and Woledge 1982, 1983). Similarly in reproductive ryegrass swards the photosynthetic potential of developing leaves is maintained because each successive leaf is carried by stem extension to the top of the canopy (Woledge 1978, 1979). The leaf angle of reproductive tillers is also greater than on vegetative tillers enabling greater light penetration in reproductive swards (Davies 1977).

Canopy structure may influence the canopy microclimate energy budget and photosynthetic rate of individual leaves (Sheehy and Cooper 1973), temperature profiles (Peacock 1975a), net transfer of heat into the soil and exchange of CO_2 and heat with the bulk air (Sheehy and Peacock 1977). However Sheehy (1977) concluded that the range of canopy structures found in temperate grasses is unlikely to be great enough for significant improvements to be made in light distribution within the canopy and hence canopy photosynthesis.

The gross canopy photosynthesis in reproductive swards is higher than that in vegetative swards (Woledge and Leafe 1976, Parsons and Robson 1981). Some reasons for this have already been discussed. Deinum (1976) suggested that this was due to stem elongation acting as a powerful sink for assimilates but Parsons and Robson (1981) showed that this increase may occur before stem elongation.

2.2.3.1.2 Leaf appearance and extension

Leaf growth per tiller is dependent on the rates of leaf appearance and extension. These usually increase in spring to peak in summer and decline through the autumn to a low in winter (Hunt and Brougham 1966, Chapman et al

1983). The rate of leaf appearance is, in part determined by the rate of leaf extension (Grant et al 1981a). Both leaf appearance and extension rates are dependent on temperature (Anslow 1966, Mitchell 1956, Williams and Biddiscombe 1965, Thomas 1975, Keatinge et al 1979b, Hunt and Field 1978, Thomas and Norris 1981, Norris 1985) and water status (Leafe et al 1977, Chu 1979, Chapman et al 1983, Barker 1983, Norris 1985), but insensitive to photoperiod (Ryle 1966, Davies and Thomas 1983, Silsbury 1970).

Management affects the rates of leaf appearance and extension in different ways. There is conflicting evidence on the sensitivity of leaf appearance to management (Chapman and Clark 1984, Davies 1974). It may be accelerated (Mitchell and Coles 1955, Grant et al 1981a) or reduced (Davies 1974) by close grazing, depending on the severity. Grant et al (1981) found that the effects of defoliation on leaf appearance was largely determined by the interaction of defoliation on leaf extension rates and the length of sheath tube through which the emerging leaf grows. Higher leaf extension rates are found with larger (Carton and Brereton 1983, Chapman et al 1983), older (Agyre and Watkin 1967) tillers with greater lamina area (Grant et al 1981a) and therefore less severe defoliation increases leaf extension rates (Wilman and Shrestha 1985). Greater rates of leaf extension (Parsons and Robson 1980, Peacock 1975b) and leaf appearance (Vine 1983) are found with reproductive than vegetative tillers. Reproductive tillers may suppress the rate of leaf appearance of vegetative tillers associated with them (Davies 1969). Although reproductive tillers have potentially greater rates of lamina growth, this may be relatively short lived as the number of leaves on reproductive tillers are limited, that is, once the flag leaf has emerged no more leaves will appear (Davies 1977).

Bircham and Hodgson (1983a,b) noted that leaf growth was much lower in Poa annua than in ryegrass, and related this to the lower position of Poa within the canopy and hence lower interception of light.

2.2.3.1.3 Tiller populations

Herbage growth is insensitive to tiller density over a wide range (Jackson 1973, Bircham 1981, Grant et al 1983). This is because a decrease in tiller density is compensated for by increases in individual tiller size (Kays and Harper 1974, Bircham 1981, Parsons et al 1984) and hence growth per tiller (Bircham 1981, Grant et al 1981a). This relationship is defined (according to the self- thinning rule) as a thinning line of slope -3/2 (Westoby 1984). Major differences between defoliation regimes may be due to disturbances to the balance between tiller density and individual tiller mass. For example, Bircham (1981) showed that growth declined under very hard continuous grazing partly because tiller density was reduced.

King et al (1984) found that net photosynthesis on recovery from hard grazing (LAI about 1) was initially less than that for continuous stocking at a similar leaf area index. This is probably due to low tiller density of the intermittently grazed sward. Korte et al (1982a) found that after an initial increase in tiller density in the first two weeks following grazing, tiller density declined and individual tiller mass increased as herbage mass increased. Therefore once defoliated, the sward would consist of a lower number of small tillers than under continuous stocking in which tiller density would have compensated for smaller tiller size. Sheath and Bircham (1983) suggest maintaining rotational grazed pastures less than 15 cm so that tiller density does not limit regrowth.

Changes in grazing severity may also influence herbage growth rates while tiller density becomes commensorate with the new defoliation regime. Bircham and Hodgson (1984) found that growth was enhanced when grazing was changed hard to lax because of greater density of large tillers (although net production was not increased because of increased senescence). Changing lax to hard however depressed growth for reasons already mentioned above.

Herbage accumulation in summer following reproductive development is often much lower than expected for the environmental conditions (Spedding and Deikmahn 1972, Anslow 1965, Anslow and Green 1967). Jewiss (1972) recognised that regrowth at the time of infloresence emergence depended on the number and size of any replacement tillers or old vegetative tillers. Anslow (1965) also noted that in Timothy 'the size attained by tillers formed in June was insufficient to maintain herbage production at a high rate'.

Davies (1977) and Davies et al (1981) showed that regrowth above defoliation height (in this case cutting height) was dependent on tiller origin and type, and was relatively independent of tiller density. Swards with high proportions of tillers formed after the decapitation of large numbers of reproductive tillers had lower regrowth than swards where vegetative tillers were older and larger, especially if a high density of immature reproductive tillers remained in the sward. Jewiss (1972) also found that under infrequent cutting the majority of vegetative tillers going into summer originated from the bases of decapitated reproductive tillers, and this may lead to poor persistence in swards where moisture stress or severe shading occurs while there are large numbers of young, small tillers (Davis et al 1981, Tallowin 1981). Under continuous grazing however, Tallowin (1981) reported that there was a wide spectrum of tiller age classes throughout the spring and suggested this should lead to greater production and persistence of the sward.

Korte (1981,1982) found that differences in tiller density caused by hard and lax grazing were still apparent the following June and may have caused the lower green herbage accumulation over the summer and autumn (Korte et al 1984). Barker et al (1985) showed that higher tiller density before a summer drought resulted in higher tiller density upon rewetting and found some evidence of a yeild advantage in the autumn with the greater tiller density. There were however no differences in yeild during the summer drought. Sheath and Bircham (1983) recommended that surplus herbage on previously infrequent or laxly grazed swards be removed so that, with adequate moisture, tiller density recovers and subsequent herbage accumulation is improved.

2.2.3.2 LAMINA SENESCENCE

Herbage senescence has a large influence on net herbage accumulation (Campbell 1964, Brougham 1966, Hunt 1965, Hunt 1970, Korte and Sheath 1978) and is a major factor influencing the relative productivity of pastures under different management systems (Hodgson and Wade 1978). Rates of leaf senescence may exceed 50 kgDM/ha/day (Wade et al 1976).

Lamina weight declines after attaining maximum dry weight. In ryegrass the weight of dead leaf is 0.3-0.4 of maximum dry weight (Vine 1977, Robson and Deacon 1978). Leaf death increases with increased temperature (Thomas and Norris 1981, Bowman et al 1982). Hunt and Field (1978) reported that leaf death in ryegrass was minimal at temperatures less than 10°C, 10% of growth at 17-30°C and 20% of growth at 33°C. At 35°C there was total plant death. This temperature effect (especially below 30°C) may be related to leaf appearance rates (Wilman and Mares-Martin 1971). Vine (1983) found that the seasonal pattern of leaf death was similar to leaf appearance but lagged behind by one leaf appearance interval. That is, there was a significant correlation between leaf death interval and the preceding leaf appearance interval. Jones et al (1982), under continuous stocking, found that there were two distinct phases of leaf turnover during spring. From July (Northern Hemisphere) the appearance of each new leaf was accompanied by the death of the oldest. In May and June the rate of leaf appearance first exceeded then was less than the rate of leaf death. This was probably associated with the greater longevity of leaves on reproductive tillers.

Leaf death (and plant mortality) is increased with more severe moisture stress (Bowman et al 1982, Leafe et al

1977, Chu 1979) and losses due to frost damage can be high (Agyre and Watkin 1967), especially with longer herbage (Parmenter and Boswell 1983).

Leaf death is directly related to the amount of herbage present (Hunt 1970) and growth rate (Grant et al 1981a). Under infrequent defoliation leaf death increases as herbage mass, pasture height or LAI increase (Hunt 1970, 1971, Wilman and Mares-Martin 1977, Morris 1970), especially once canopy closure has been reached (Hunt 1965, Hunt and Brougham 1967, Tainton 1974a). A re-evaluation of the data of Hunt (1970a) (see Korte 1981) showed that herbage died at a rate of 0.8% of green herbage per day regardless of stage of growth or shading. This linear increase of leaf death with herbage mass is also apparent in studies of continuous stocking (Grant et al 1983, Bircham and Hodgson 1983a,b). A figure of 2% is suggested by the data of Bircham (1981). Carton and Brereton (1983) attributed this to the greater size of tillers at higher herbage mass, the greater proportion of aged tissue and decreased light penetration of these swards.

2.2.3.3 TISSUE DISAPPEARANCE

Rates of tissue dissappearance from the sward are dependent on the rates of tissue death. Once death is greater than maximum tissue disappearance, dead herbage will accumulate in the sward (Hunt 1970a).

Soil moisture (Campbell 1964, Bowman et al 1981) and temperature (Hunt 1977) are both determinants of the rate of tissue disappearance. Leaf disappearance is faster than stem disappearance (Wade et al 1976), probably because tissue that is not in contact with the soil will not decay very rapidly (G.W. Sheath pers. comm.). The trampling of dead herbage into the ground may therefore be very important in its disappearance.

2.3 EFFECT OF DEFOLIATION ON HERBAGE MASS COMPONENTS

Defoliation frequency and intensity are often defined or described in terms of the resultant changes in herbage mass. Obviously then, management of a pasture directly effects its herbage mass. What is more important is the influence of management on changes in the level, composition and structure of herbage mass over time. These changes in the pasture are a result of both herbage accumulation (section 2.2) and herbage removal by defoliation. The intake of grazing sheep appears primarily determined by the leaf lamina content of the pasture (Barthram 1981, Barthram and Grant 1984) and intake largely consists of lamina unless grazing is very severe (Guy et al 1981, Bircham 1981).

Changes in the lamina component relative to the stubble and dead components are therefore very important and defoliation management can have a large influence on this. For example, in vegetative swards recovering from a close cut in summer, Hunt (1965) found that soon after 95% light interception was reached the mass of leaf blade declined and the mass of senescent and dead herbage in the sward increased. It was also found that when a perennial ryegrass sward was leniently (at >90% light interception) defoliated at weekly intervals in the late summer (Hunt and Brougham 1966,1967) the ratio of leaf blade to leaf sheath declined in the sward. The yeild of dead matter increased at an almost linear rate throughout that time. Ollernshaw and Hodgson (1977) also observed considerable accumulation of dead and senescing material in the stubble of leniently defoliated ryegrass swards.

Jackson (1974,1975) studied the effect of cutting at constant heights (3, 6, 9 or 12 cm), or interspersed with one 3 cm cut, on sward morphology and herbage mass. It was observed that as constant cutting height increased the quantity of stubble residue, mean level of apex above ground and the height of insertion of the lowest green leaf blade all increased. The depth of leaf in the sward increased with greater cutting height but the difference was much greater between 3 and 6 cm (having a 1.3 cm difference) than between 9 and 12 cm (having a 0.4 cm difference). The total weight of leaf lamina before cutting did not differ between cutting heights and was 1505 kgDM/ha on average. The effect of a single close cut was to increase leaf depth after cutting and total weight of leaf prior to cutting for up to 5 harvests in the 9cm and 12cm cutting heights.

Changes in vegetative pastures due to management, however, may be small compared to the changes that may occur in reproductive pastures over the spring and early summer. One reason for this is the better growing conditions that usually occur at this time of the year but the most important factor is the level of reproductive development in grasses. Ceiling yeilds in reproductive pastures have been measured at 9-16 t DM/ha under high fertility conditions (Brougham 1959a, Green et al 1971, Corrall et al 1979), but in summer (even when moisture in not limiting) ceiling yields seldom reach half these values (Hunt and Brougham 1967) and in winter are very much lower (Brougham 1959a).

Previous discussion has shown that in vegetative swards differences in the composition of herbage mass is largely due to changes in the mass of dead and senescent herbage rather than large changes in the proportions of leaf and stem in the green herbage. However Korte et al (1982b, 1984) concluded that the major difference between reproductive swards managed differently in spring (i.e. hard versus lax grazing) was the mass of reproductive stubble. It was found that reproductive tillers contributed little to herbage mass until October in the Palmerston North (N.Z) environment and therefore rapid changes in herbage mass associated with reproductive development did not occur until that time. By November, however, reproductive tillers accounted for 90% of ryegrass herbage mass in lax grazed pastures. Wilman et al (1976a) also found that when a reproductive sward of Italien ryegrass was spelled for 14 weeks most of the increase in yeild was attributable to reproductive stem and inflorescence. Holmes and Hoogendorn (1983) noted that the stubble mass of laxly grazed swards was more than three times that of hard grazed swards and was the major contributor to the higher herbage mass of the laxly grazed swards.

Reproductive development results in an increased proportion of stem and dead herbage and a lower proportion of lamina (Wilman et al 1976a,d, Korte 1981, Holmes and Hoogendorn 1983, Bartholomew and Chestnutt 1978). These changes are greater with lax (Korte 1981, Holmes and Hoogendorn 1983) and infrequent (Wilman et al 1976a) defoliation.

Very hard grazing (removal of almost all lamina) has been shown to be effective in ensuring leafy regrowth from a population of mainly vegetative tillers rather than continued development of reproductive tillers which are increasingly less leafy (Korte et al 1982b, 1984, Hughes 1983). This is because once flower initiation has occurred (see section 2.4.3) there is no further development of leaf initials on reproductive tillers (Davies 1977). The flag leaf usually appears within 10 days of floral initiation and the number of leaves on the tiller then starts to decline (Davies 1977, Vine 1983).

Increased reproductive development in spring subsequently results in increased dead herbage content of the pasture as a result of reproductive tiller death. Korte et al (1984) found that during summer dead herbage mass increased rapidly to contribute more than 40% of total herbage mass by late summer. Herbage mass may remain high on lax and/or infrequently defoliated swards until well into autumn or winter unless attempts are made to remove (mainly dead) reproductive herbage (Korte 1981, 1982, Sheath and Bircham 1983).

Reproductive development of grasses also changes sward canopy structure. For example, Hodgson and Maxwell (1982) noted that 'in a reproductive sward there is a much more heterogenous admixture of leaf and stem, or of immature and mature leaf in all layers of the sward compared to a vegetative sward. In these cases too, the sward canopy will tend to be taller and to have a lower bulk density'. Ryegrass stem and seedhead is elevated through the canopy with a corresponding elevation of leaf and a lower proportion of total herbage mass in the lower horizons (Anslow 1967).

Changes in sward height over the spring are closely related to reproductive tiller development because of the changes in the apex length of reproductive tillers (Davies and Calder 1969). Wilman et al (1976a,d, 1977) found a close relationship between sward height and stem plus inflorescence herbage mass.

Sward digestibility follows a seasonal pattern, largely determined by grass reproductive development (Raymond 1969). Digestibility declines over spring and summer, and rises again over the autumn, winter and early spring (Rattray 1978a,b).

The overall digestibility of the sward is determined by the proportions and digestibility of individual components. The digestibility of new and expanding leaves is always high (0.8-0.9) but total digestibility may decline slightly over the ryegrass reproductive period (Hodgson and Maxwell 1982, Hacker and Minson 1981). This is probably due to an increased proportion of older senescent leaves which have lower digestibility

(0.7)(Hodgson and Maxwell 1982).

The digestibility of leaf sheath is similar to leaf lamina (Laredo and Minson 1975) and shows little seasonal change (Hodgson and Maxwell 1982). The digestibility of dead herbage is always low (0.3-0.4)(Rattray 1978a,b), and sward digestibility has been related to the proportion of dead herbage in the sward (Rattray 1978a,b, Korte 1981, Francis and Smetham 1984).

The digestibility of reproductive stem, however, shows marked changes during development. The digestibility of stem is initially high but falls to low levels as the tiller matures and finally dies (Hodgson and Maxwell 1982, Hacker and Minson 1981, Terry and Tilley 1964, Minson et al 1960). In ryegrass, this decline is slow until ear emergence but very rapid thereafter (Raymond 1969). Browse et al (1984) found that sward digestibility in late spring was related to the proportion of reproductive stem in the sward.

The rapid decline in digestibility in undefoliated swards is delayed to a varying extent by defoliation (Swift and Edwards 1980, 1983, Browse et al 1981, 1984). This is probably a result of defoliation influencing the relative proportions of vegetative and reproductive tillers in the sward (Davies 1971) and the degree of reproductive development in the sward (Minson et al 1960). Less frequent (Wilman et al 1976a,c, Edelsten and Corrall 1979) or intense (Holmes and Hoogendorn 1983) grazed swards usually have lower digestibility.

2.4 EFFECT OF DEFOLIATION ON TILLER DEVELOPMENT AND POPULATION DENSITY

The dynamics of tiller populations determine the persistence and botanical composition of the sward and may also influence herbage production. This section will review the factors influencing the formation and death of both vegetative and reproductive tillers and the effect of defoliation on the resultant tiller density.

2.4.1 TILLER APPEARANCE AND DEATH

The potential rate of tiller appearance is determined by the leaf appearance rate (Davies 1977, Davies and Thomas 1983) as tiller buds are situated at the base of each developing leaf primordia (Jewiss 1972). Tiller appearance does not often reach potential levels because other factors are important in the suppression or release of tiller buds. These have been reviewed by Dorrington-Williams (1970) and Davies (1977).

Both temperature and light (and the interaction between them) have an important role in determining the rate of tillering (Mitchell 1953b, 1954, Mitchell and Lucanus 1960, Mitchell and Coles 1955, Ryle 1964, Langer 1963). These workers found that low temperature, particularly at night, was beneficial for development of buds into tillers. It was found that there was a higher rate of tillering under long day rather than short day conditions, possibly an influence of the total light energy received. Reduced intensity of light also reduced the number of tillers produced. The amount of light reaching tiller bases is a more important factor influencing tiller appearance rates rather than the amount of light at the top of the canopy (Davies 1977). Tiller appearance is also markedly reduced by moderately severe water stress (Korte and Chu 1983, Barker 1983) but seems unaffected by mild water stress (Garwood 1969).

With the initiation of reproductive growth the development of tiller buds on reproductive tillers ceases (Dorrington-Williams 1970, Langer et al 1964, Langer 1956). This is the phenomenom of apical dominance (Jewiss 1972, Laidlaw and Berrie 1974). Tillering normally resumes at ear emergence (Langer et al 1964, Jewiss 1972, Hebblethwaite et al 1980, Brougham 1961).

Any stress or combination of stresses which results in a negative tiller carbohydrate balance is likely to cause tiller death (Davies 1977). These stresses include low carbohydrate status of stubble (see Davies 1977) in overgrazed swards (Alberda 1966), decapitation of reproductive tillers (Davies 1977), shading (Kays and Harper 1974), nutrient stress (Aspinall 1961, Ong 1978) and moisture stress (Korte and Chu 1983). The main factor though is the canopy light environment (Ong 1978, Ong et al 1978). The tillers which die first are usually the smallest or youngest on the plant, irrespective of position. These tillers have no more than two leaves and are completely dependent on the roots of the parent tiller for water and nutrients.

Although tiller death may occur at any time of the year a high death rate has often been reported to coincide with ear emergence or to occur during early reproductive growth (Langer et al 1964). Ong et al (1978) found that tiller death coincided with the period of stem elongation and was largely due to the failure of large flowering tillers to support the growth of the shaded young vegetative daughter tillers associated with them, despite good vascular connections.

Tillers may also die as a direct result of grazing. Both Davies (1971) and Korte et al (1982a) observed an increase in tiller death during the first two weeks of regrowth under intermittent cutting. This was possibly due to to physical damage to tillers rather than a reduction in assimilate supply as tiller appearance more than offset these losses. Bircham and Hodgson (1983a,b) report high losses in very hard (<700 kgDM/ha) grazed continuously stocked pastures. The reason for this was probably uprooting of tillers by the grazing animal. Similarly, low tiller numbers are indicated in the data of Brougham (1959b) when swards were cut frequently to a low height (2.5 cm), especially during dry summers.

2.4.2 TILLER POPULATIONS AND MANAGEMENT

It is clear that the major factor influencing the tiller density is the light environment within the sward. It is modified by the influence of reproductive development, moisture and nutrient status and the effects of grazing. The quantity of light available to the sward increases mid-winter to mid-summer and declines thereafter. Under continuous grazing to a constant height tiller numbers may be expected to follow this pattern (Grant et al 1981b).

As grazing height (or herbage mass) increases tiller density falls and individual tiller mass increases (Kays and Harper 1974, Grant et al 1981b,1983, Bircham 1981, Bircham and Hodgson 1983a,b). If the grazing intensity is changed (that is, herbage mass is increased or decreased), tiller populations will change over a period of up to 4-6 weeks to become commensorate once again with current herbage mass (Bircham and Hodgson 1984).

In many experiments (though almost exclusively under infrequent cutting), large fluctuations in tiller numbers between seasons were evident (Brougham 1959b, Langer et al 1964, Silsbury 1964, Garwood 1969, Wilman et al 1976d, Hunt and Field 1978, Davies and Simons 1979, Korte 1981). Most of these reports show that tiller numbers increase in the autumn, winter and early spring and decline from just before ear emergence to autumn. This fluctuation is mainly caused by the influence of reproductive development in spring (Langer et al 1964).

Tiller numbers under intensive (frequent and relatively severe) management however, show relatively little change throughout the season compared to infrequent cutting management (Grant et al 1981b). Increasing the frequency and/or severity of grazing generally promotes higher tiller densities (Wilman et al 1976a,c, Korte 1981), and for this reason tiller density under continuous stocking is usually greater than under rotational grazing (Tallowin 1981, Chapman et al 1983, Chapman and Clark 1984). It may also result in a more homogenous mixture of vegetative tiller ages and size because greater numbers are formed throughout the spring (Jewiss 1972, Davies et al 1981, Tallowin 1981). This may be important for subsequent summer survival and growth especially under adverse conditions (Davies 1971, Hill and Watkin 1975, Davies 1977, Davies et al 1981, Tallowin 1981).

Tiller numbers are usually higher under grazing than cutting (Jones 1981). Davies and Evans (1982) suggested that this may be due to the effects of treading. When cut swards were pounded with wood to simulate treading the accumulations of old dead sheaths were broken up and new short tillers were formed below cutting height.

2.4.3 RYEGRASS REPRODUCTIVE DEVELOPMENT

There are three stages in ryegrass reproductive development: floral induction, floral initiation and inflorescence development (Jewiss 1972).

The change in ryegrass tillers from vegetative to reproductive growth occurs in early spring after certain inductive requirements have been met (Jewiss 1972). Ryegrass tillers are induced to flower by low temperatures and short days (Wilson 1959, Cooper and Calder 1964, Keatinge et al 1979a).

The ability of tillers to produce seedheads depends on the time of initial tiller appearance, and the position of the tiller within the plant. Those tillers produced in the autumn have a greater chance of flowering, especially if inserted on the main stem (Langer and Lambert 1959, Hill and Watkin 1975, Wilson 1959). In 'Grasslands Ruanui' few tillers appearing after early September became reproductive in Palmerston North (Hill and Watkin 1975, Wilson 1959).

The events following vernalisation have been described in detail (Wilson 1959, Jewiss 1972, Davies 1977, Hebblethwaite 1977, Langer 1979, 1980, Simon and Park 1982, Matthews 1979b).

Initiation of flowering takes place once the vernalisation requirements have been met. Wilson (1959) found, in the Palmerston North, NZ environment, that no floral initiation was observed in winter or after late December in a range of species. Ryegrass initiated floral primordia mainly within a short (9 day) period in late September. The timing of initiation is largely determined by day length (Keatinge et al 1989a). Initiation is characterised by the development of a 'double ridge', heralding the formation of a spikelet rather than a single ridge as in leaf primordia development (Jewiss 1972).

Further development is accompanied by an exponential increase in stem mass and length. The developing reproductive apex and leaves are thus carried above ground level (Jewiss 1972). This subsequent growth and development towards ear emergence is mainly influenced by temperature (Keatinge et al 1979a, Habjorg 1980). Korte et al (1984) found that ryegrass tillers with stem elongation appeared from mid September (meaning earlier initiation than found by Wilson (1959)) and these rapidly increased in number during October. Approximately 2400 reproductive tiller/m^2 developed through this period (a similar number to that found by Hebblethwaite (1977)) and a further 1000/m^2 developed in November and December. Very few reproductive tillers developed after December. The later formed tillers have a smaller mass and shorter stems than the earlier formed tillers (Hill and Watkin 1975, Hebblethwaite et.al 1980).

Inflorescence emergence is usually 25-42 days after floral initiation (Wilson 1959, Langer 1980). Korte et al (1984) at Palmerston North found that first inflorescence emergence occured in early November whereas in the trials of Wilson (1959), at the same location it had begun two weeks earlier. This may be due to differences in temperature. The majority of inflorescence emerge 3 to 4 weeks after the first (Wilson 1959, Korte et al 1984). Once emerged, and if the apex is not removed, development continues until seed ripening and tiller death about 60 to 70 days later (Hebblethwaite 1977).

Defoliation may have a large influence on reproductive development by removing reproductive meristems (causing the death of reproductive tillers) or reduction in the size of surviving tillers.

At some point between initiation and ear emergence, the reproductive apex is elevated within the canopy to a height where it can be removed by cutting or grazing (Aitken 1966). Hard grazing will remove more reproductive tiller apices than lax grazing as there will be a greater number of apices above grazing height, and animals will be less able to avoid consuming them (Davies 1971, Binnie et al 1980, Korte 1981, Hughes 1983).

Under a conservation regime it appears unlikely that many reproductive tillers will develop subsequent to cutting and regrowth is mainly from vegetative tillers (Davies 1977, Browse et al 1981, 1984). However under more intensive management, it appears that up to 50% more reproductive tillers may develop after removal of existing reproductive apices and if conditions remain favorable (Langer 1957, Wilson 1959, C.J. Korte pers. comm.). These latter tillers, unless removed also, will ultimately be smaller than earlier tillers.

Hill and Watkin (1975), Davies (1971) and Brown (1980) found that grazing may reduce the size (and mass) of the reproductive stem. This is probably the result of the inverse relationship between total tiller density and individual tiller size (Donald 1963, Harper 1977, Bircham 1981, Chapman et al 1983).

"Delayed" reproductive development has been found in more severely and/or frequently defoliated swards. Brougham (1961) showed that the period of stem elongation was later in continuously (7.5–15.0 cm) than rotationally grazed (22.3-37.5 cm to 7.5–10.0 cm) swards. Inflorescence emergence was also delayed. Chapman et al (1983) found that mean ryegrass inflorescence emergence date at Ballantrae, P.N., was 16 December under intensive grazing, which was much later than expected. This was probably due to defoliation of early formed tillers by intense, frequent grazing and it was probably not until mid-November that herbage mass increased to an extent that reproductive tillers were able to emerge and mature without being consumed. The later formed secondary tillers would probably have made up a large proportion of those finally reaching maturity (Brown 1980, Chapman et al 1983).

2.5 EFFECT OF DEFOLIATION ON BOTANICAL COMPOSITION

The botanical composition of a pasture is determined by three interrelated factors: competition, stress (light,nutrients, water etc) and disturbance (defoliation etc)(Grime 1974, 1979a,b). Rhodes and Stern (1978) and Rhodes and Ngah (1983) have stressed that differences in the yeild and botanical composition of a species mixture is dependent on the yeilding ability of individual species (under current conditions of stress and disturbance) and the competitive ability of each species. Competition between neighbouring plants occurs when each seeks to utilize the same factor and when the immediate supply of that factor is below the combined demand of the plants (Donald 1963).

These factors will be reviewed with particular reference to the perennial ryegrass, white clover and Poa spp components of a mixed sward.

White clover is a valuable component of New Zealand swards because of nitrogen fixation, improved seasonality of production and improved nutritive value of the pasture (Haynes 1980). Net herbage accumulation of pastures may depend directly on the proportion of clover in those pastures especially under conditions of low fertility (Curll et al 1985).

Ryegrass and white clover show differences in yeilding ability under different management and environmental conditions because of differences in nutrient requirements (Haynes 1980), light (Langer 1973, Woledge and Dennis 1982, Beinhart 1963) and temperature (Mitchell 1956, Beinhart 1963) responses, reproductive development (Anslow 1965), height (Rhodes and Stern 1978) and response to grazing (Edmond 1964, Curll and Wilkins 1982, Curll 1982). These differences may mean that ryegrass and white clover are to some extent complimentary in their growth patterns (Haynes 1980). However, ryegrasses are almost always more competitive than clovers in both root and shoot competition (Harris and Thomas 1973, Rhodes and Ngah 1978, Martin and Field 1984). In fact, Ennik (1970) has stated that clover is more or less bound to the space left by the grass. This is indicated in the results of Harris and Brougham (1968) and Harris and Thomas (1973) who found that white clover content was increased by the lack of persistence of 'Grasslands Manawa' ryegrass. Camlin (1981) also found that the 'compatability' of grasses with clover was inversely related to the persistence of those grasses. Improvement in the summer growth of grasses often leads to a decline in white clover growth (Lancashire et al 1978, Chestnutt and Lowe 1970) and clover content may be higher under cattle than sheep grazing because of lower grass tiller density under cattle (Boswell and Crawford 1978, Clark et al 1982). The use of chemicals such as Paraquat (Rolston and Chu 1976) or Mefluidide (Goold et al 1982) severely limit grass growth and increase clover content (Thorn and Perry 1983) as does selective grazing of grasses by goats (Clark et al 1984).

The yeild of white clover is related to the length and weight of stolon (Baines et al 1982, Wilman and Aseigbu 1982 a,b, Hay 1983, Hay and Chapman 1984), and numbers of growing points (Woledge and Dennis 1982).

The amount of stolon in a sward is very low at the start of spring (Hay 1983) because stolon branching is restricted during winter by low temperature (Beinhart 1963) and because of stolon losses associated with winter burial of stolons by earthworms (Hay 1983, Hay et al 1983, Hay and Chapman 1984). Branching is also restricted in summer by high temperature and low soil moisture (Beinhart 1963) and during periods of moisture stress large losses (up to 70%) of stolon mass may occur (Hay and Chapman 1984).

The late spring/early summer period is therefore critical for the development of stolon mass that will determine white clover growth over summer and autumn. Stolon development is dependent on light (Beinhart 1963, Woledge and Dennis 1982) and therefore grazing severity and frequency can radically alter stolon development during this period. Hay and Baxter (1984) have shown that set stocking in spring may result in greater clover production over summer than does rotational grazing especially if spells between grazing are long.

Sheath and Bircham (1983) have also shown that the content of white clover in summer is significantly reduced when lax grazing resulted in high herbage masses over November and December and summer grazings were hard. The data presented by Sheath and Bryant (1984), combined for easy and steep contours, show that the legume leaf content of herbage mass during Januaury-March was 25%, 22% and 15% respectively as a result of fast rotations, continuous stocking, and uncontrolled grazing from November to Januaury.

Wells and Hagar (1984) have shown that Poa annua is not an aggressive species (Bircham 1981) but one very adept at colonizing swards where the competitive ability of ryegrass was low. Poa annua ingression often follows periods of intense grazing (Wells 1974) and may be greater on swards previously lax grazed in spring (Korte 1981).

CHAPTER 3 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted from 19 September 1983 to 12 March 1984 (24 weeks) on the Pasture and Crop Research Unit of Massey University, Palmerston North, New Zealand (grid reference NZMS1, N149/099308).

The site was relatively exposed and flat, on the top terrace of the Manawatu River (Plate 3.1).

The soil type is a Tokomaru silt loam (Cowie et al 1972). It is classified as an Aeric Fragiaqualf (gleyed, yellow-grey earth) (Cowie 1978). It is characteristic of large areas of flat to rolling hill country at the foot of the western Tararua Ranges.

The site had been sown 2 years previously with a 'Grasslands Nui' ryegrass/ 'Grasslands Huia' white clover mixture. Recent drainage had left 3 lines of bare soil through the paddock. These were used for access to the

Plate 3.1 Experimental Site at Massey University

plots which were placed to avoid these areas. A soil test taken on 18.8.83 indicated that soil fertility was satisfactory (Olsen P=14, K=7, pH=5.8).

Monthly climate data collected at the metereological station at Grasslands Division, D.S.I.R., Palmerston North, are presented in Appendix 1. A comparison of data for 1983/84 with the 40 year mean indicates that September and Februaury rainfall was greater than normal whereas that of November, Januaury and March was less than normal. Early spring temperatures were higher and summer temperatures lower than normal. A detailed daily record of climate data from the same station, approximately 2 km from the trial site, are given in Appendix 2.

3.2 Experimental Treatments and Post-Treatments

3.2.1 Introduction

In August and September 1983 a paddock adjacent to the meterological station on the Pasture and Crop Research Unit was subdivided with 4 wire electric fences into 24 plots each 180 m^2 . Six grazing treatments were compared in four replicates, laid out in a randomized complete block (RCB) design (Figure 3.1). To spread the work load, and because the numbers of sheep that could be used to graze the trial were limited, pairs of replicates (1 and 4 vs 2 and 3) were grazed on different days.

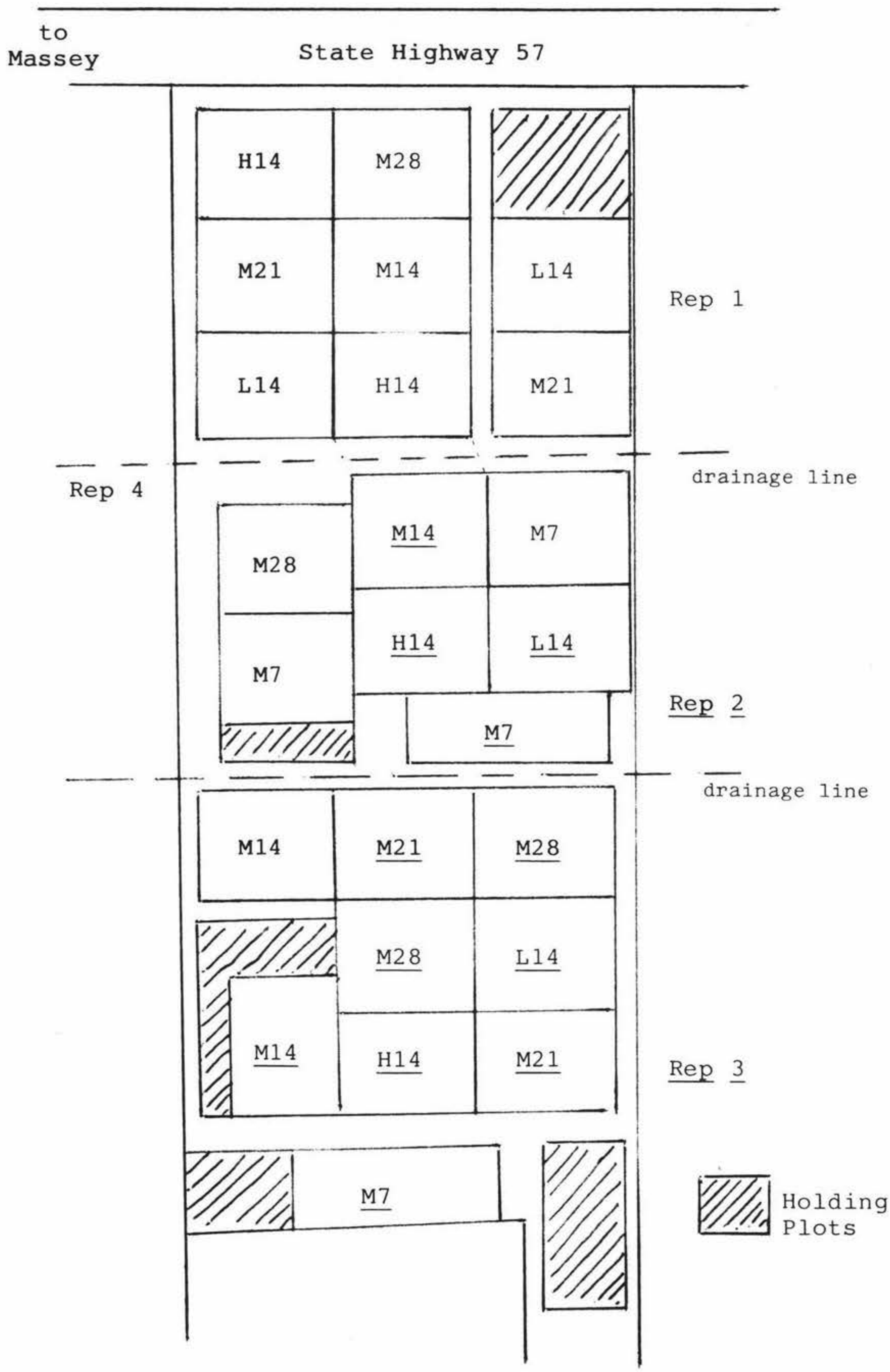
There were two periods of measurement. The grazing treatments were compared over the 83 day (12 week) period from Sept 22 (Sept 26) to Dec 14 (Dec 18) for replicates 1 and 4, and (2 and 3) respectively. This period (days 0 to 83) is designated the 'treatment' period.

Subsequent pasture performance was assessed over a further 84 days (12 week) period from Dec 16 (Dec 20) to Mar 8 (Mar 12) under a common management. This period (days 85 to 168) is designated the 'post-treatment' period.

Each grazing, with either ewes and lambs, hoggets or wethers, lasted one day except for the initial grazing (for which there were insufficient sheep, thus delaying the start of the trial) and the final grazing of the treatment period which was over 2 days.

3.2.2 Treatment Period

Figure 3.1 Trial Layout



The six treatments were a comparison across grazing intensity and grazing frequency (Table 3.1).

The three grazing intensity treatments were hard (H); moderate (M) and lax (L). These were compared under a 14 day rotation length (13 day regrowth interval). Residual lamina mass (kg lamina DM/ha) was chosen as the intensity criteria. This was because of the importance of lamina mass to both animal and pasture productivity (see Chapter 5.9). Also the alternatives (green or total herbage mass) are very much more variable in spring and summer because of the influence of ryegrass reproductive development, as discussed in the previous chapter. Intensity treatments were designated H14, M14 and L14, and corresponding residual lamina mass were approximately 150 (100-200), 450 (400-600), and >750 kg DM/ha.

The frequency treatments were at 7, 14, 21 and 28 day rotation lengths (6, 13, 20, and 27 day regrowth intervals respectively), and were at the moderate (M) level of grazing intensity. The frequency treatments were designated M7, M14, M21 and M28. The M14 treatment was, therefore, common to both the intensity and frequency comparisons.

Table 3.1 Grazing Treatments

Residual Lamina (kgDM/ha)	Rotation Length 7	14	21	28
2-300		X		
4-500	X	X	X	X
700		X		

Table 3.2 Grazing Schedule

Day	Grazing Dates Replicate 1,4	2,3	Treatments Grazed 7	14	21	28
0	22.09	26.09	x	x	x	x
6-7	28.09	2.10	x			
13-14	5.10	9.10	x	x		
20-21	12.10	16.10	x		x	
27-28	19.10	23.10	x	x		x
24-35	26.10	30.10	x			
41-42	2.11	6.11	x	x	x	
48-49	9.11	13.11	x			
55-56	16.11	20.11	x	x		x
62-63	23.11	27.11	x		x	
69-70	30.11	4.12	x	x		
76-77	7.12	11.12	x			
83-85	14.12	18.12	x	x	x	x
119-120	19.01	23.01	x	x	x	x
168	8.03	12.03	x	x	x	x

Table 3.2 shows the actual grazing regime for each treatment with the corresponding day (i.e. days 0 to 168) and date.

3.2.3 Post-treatment period

All plots were hard grazed (to 200 kg lamina DM/ha) over 2 days at the end of the treatment period (days 83 to 85). The plots were then spelled for 34 days until day 119 (Jan 19 or 23), when they were all grazed to a common residual of 450 kg lamina DM/ha. A final harvest was taken 48 days later on day 168 (Mar 8 or 12), although further measurements were carried out on the plots by M.A. Richardson and C.C. Bell (Research Division, Batchelor Agricultural Centre, Ministry of Agriculture and Fisheries). Their report is presented in Appendix 8.

3.3 Measurements

3.3.1 Introduction

Measurements were chosen so that, within the constraints of available labour, as complete a picture as possible of sward changes could be contructed and the importance of different sward characteristics in those changes established.

Before and after each grazing throughout the trial measurements were made of herbage mass and sward height. From a subsample of cut herbage, dissections and measurements of leaf area index (LAI) and population density were carried out.

During the treatment period light interception measurements and counts of emerged inflorescence were also done before grazing. Immediately before days 0, 83, 119 and 168 population densities were assessed by taking 30 tiller cores. Before days 0 and 83 sward structure and *in vitro* OM digestibility was assessed.

There were problems in the use of residual lamina as the grazing intensity criteria as quick identification of lamina mass was needed in the field, especially with regard to initial allocation of sufficient sheep to plots and withdrawal of sheep from plots once the desired lamina mass was achieved. Although herbage estimations were done before the trial to determine the relationship between lamina mass and green or total herbage mass, the grazings over the first two weeks of the treatment period were largely, though successfully, based on 'educated' guesses. These initial grazings provided experience in eyeball estimation of lamina mass and the data for calibration of a single-probe capacitance meter (Design Electronics Pasture Probe) which was subsequently used as an aid to estimation of lamina mass (Appendix 7).

3.3.2 Herbage Mass

Ground level cuts using a Sunbeam electric shearing hand-piece and three 0.24 m^2 (0.8m * 0.3m) quadrats were made before and after each grazing. Following cutting herbage was washed to remove soil and dung, and then weighed. A 400-900g subsample was dried at 80 $^{\circ}C$ for 24 hours to obtain the dry matter content of the herbage. Herbage mass was calculated from the fresh weight (g/m^2) and dry matter content of the herbage.

3.3.3 Herbage Dissections

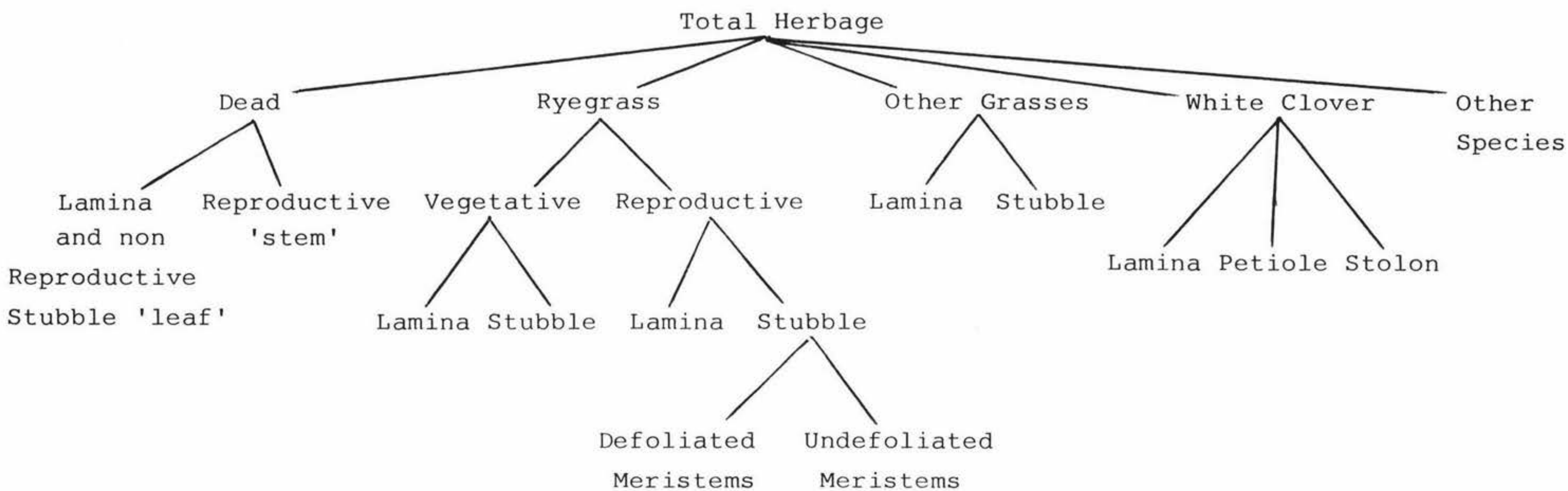
A subsample of cut herbage was dissected to estimate the mass of individual herbage components and botanical compositions. Sufficient herbage (usually 10-20g) was taken so the each dissection took between 30 and 45 minutes to complete.

Details of the dissections are shown in Figure 3.2. No attempt was made to distinguish between true stem and pseudostem for reproductive ryegrass tillers and therefore all non-lamina herbage in grasses is designated as 'stubble'.

3.3.4 Sward Height

Measurements of sward height were by a modified technique based on that of Bircham (1981). The apparatus was constructed of a sliding plastic pipe on an aluminium rod which was marked in centimeter (cm) gradations (Plate 3.2). The point of the aluminium rod was placed on the ground and the plastic pipe was slid up the rod so that the bottom of the pipe was at the top of any herbage within a radius of 2cm of the rod. The height of the sward was then simply read off the aluminium rod. The

Figure 3.2 Herbage Dissection Components



main advantage of the technique was that the level of reading was at least 60cm above ground level.

Twenty readings were taken along both diagonals of each plot and the mean value for each plot then calculated. It was found, even with very variable, rank plots, that there was no need for a greater number of readings as mean values were always within 0.5cm of the mean of 20 readings. The readings on each plot took only 2-3 minutes to complete.

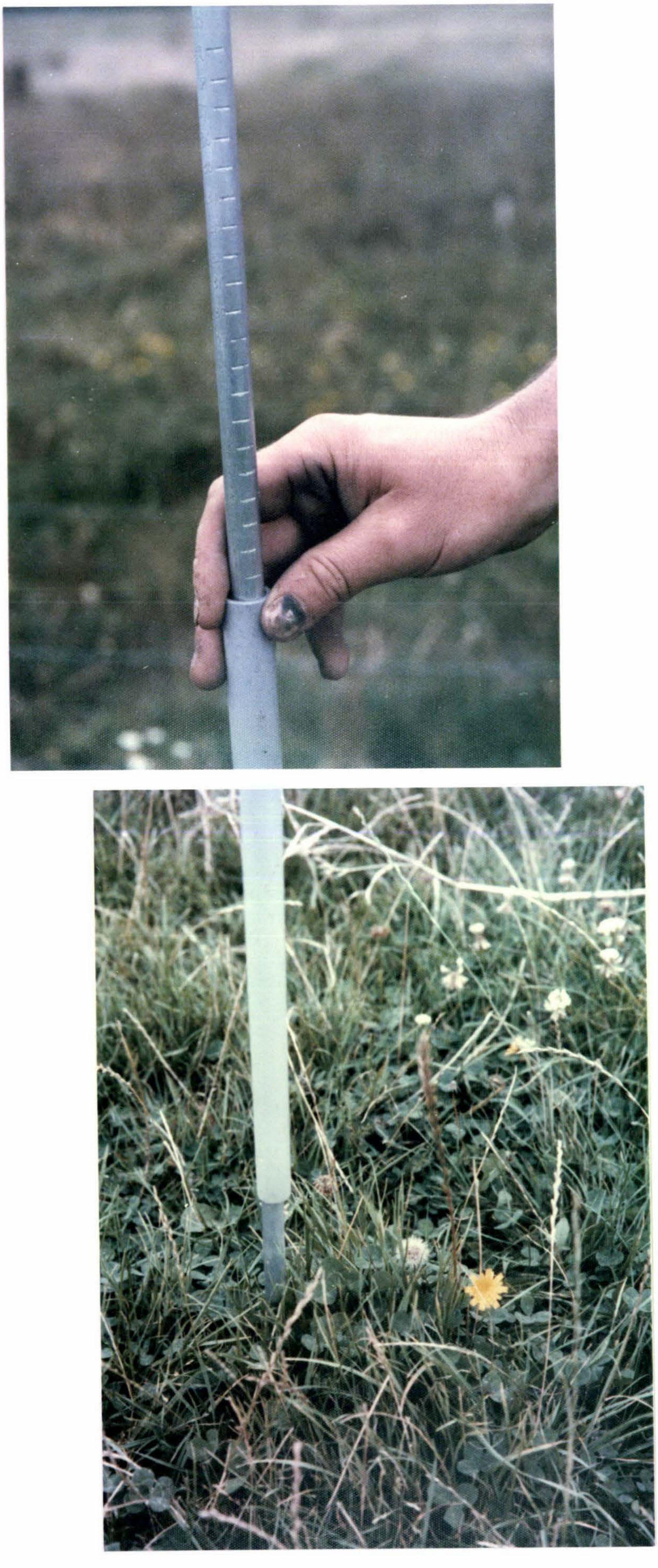
3.3.5 Population Density

Ryegrass and other grass tiller densities, and white clover stolon tip density were assessed by two methods.

1) The numbers of tillers and stolon tips in the dissection subsample were counted before and after each grazing and the densities (numbers/m^2) calculated.

2) At days 0, 83, 119 and 168 densities were determined by

Plate 3.2 Device with which Sward Height was Measured.



taking thirty 5.2 cm diameter cores per plot using the technique of Mitchell and Glenday (1958). An assessment of the densities of ryegrass, Poa spp and other grass tillers, and white and red clover stolon tips was made.

3.3.6 Emerged Inflorescence Density

Before each grazing during the treatment period the numbers of emerged inflorescence were counted within at least three 0.24m^2 quadrats per plot. An inflorescence was considered emerged when at least half the inflorescence was exposed above the ligule of the flag leaf. Densities were then calculated.

3.3.7 Light Interception

During the treatment period, light interception was measured before each grazing with a Li-Cor LI-185 quantum meter. This was done by taking 10 reading above, and at the base of, the herbage canopy on each plot. Actual light interception would have been higher than measured as the photo cell was 2.5cm above ground level.

3.3.8 Leaf Area Index

LAI was measured before and after each grazing by determining the total area of lamina for each component in every dissection subsample with a Li-Cor LI-3100 Area Meter (Li-Cor Inc, Lincoln, Nebraska, USA). The LAI was then calculated for each plot.

Because of demands on equipment at that time, LAI was not measured on day 168.

3.3.9 Canopy Structure

Immediately before days 0 and 83 the spatial distribution of herbage within the canopy was measured using a stratified clip technique (Rhodes 1971, Anslow 1967, Wade and Le Du 1982, Bircham 1981, Hughes et al 1984).

Two different techniques were used. Before day 0, the stratified clips were done in the field with an apparatus built and used by Linton (1982). This consisted of a shearing handpiece set on a vertically adjustable frame. The handpiece moved freely in the horizontal plane and clippings were collected with a powerful vacuum (courtesy of the Seed Technology Centre, MU). Four $0.24m^2$ quadrats, cut each 2.5cm, were collected from various plots. The technique proved to be very tedious and the equipment cumbersome within the confines of the plots (Linton had used the technique in open paddocks), and a different method was used before day 83.

In the second technique, one 45cm * 28 cm * 10cm sample of turf from each plot in replicate 2 was brought to the laboratory. These were laid horizontally on a pre-marked sheet of cardboard and the strata (each 4cm to a height of 20cm and every 10cm thereafter) cut with scissors. Care was taken not to disturb the canopy. The bottom strata was cut to ground level using a shearing handpiece and was the only strata washed before all were weighed and dried in an oven at 80 ^{o}C for 24 hours.

3.3.10 OM Digestibility

In vitro OM digestibility was measured on pregrazing, stratified clip and various disection samples at day 83 using a cellulase method (Roughan et al 1977, Dowman and Collins 1982).

3.4 Further Calculations

Net herbage accumulation (NHA) was calculated for each herbage component using the formula of Campbell (1966), defined algebraically as:

$$NHA = B_i - A_i + \left[\frac{(B_i - A_i) * r}{n}\right]$$

where A_i = herbage mass after grazing at the start of the rest period i

B_i = herbage mass before grazing at the end of rest period i

r = number of days paddock grazed

n = number of days between grazing or the length of rest period i

i = number of grazing cycles that NHA is computed for

The last term in the formula is a correction for growth during the grazing period.

Other data such as individual tiller mass and bulk densities were also calculated.

3.5 Data Handling

Two 'Pascal' routines were written by C.J. Korte (and subsequently slightly modified by computer centre consultants) for use on the Massey University Prime computer. These routines were used to manipulate raw field data into a form acceptable for further manipulation and statistical analysis by packages such as 'SPSS' (Nie et al 1975) and 'Minitab' (Ryan et al 1981).

In the first programme (disect#01), a file was initially created and subsequently updated with the raw data entered on a plot number basis. In the second programme (growthrate), the plot numbers were changed to treatments and replicates, and an output file of means and individual plot data created. Net herbage accumulation for each component in terms of rates (kgDM/ha/day) and totals (kgDM/ha) over a given period were calculated, the latter either corrected or not corrected for accumulation during the grazing period. An output file was created for statistical analysis.

3.6 Statistical Analysis

The two packages, 'SPSS' and 'Minitab' were used to analyse the data. SPSS was used for analysis of variance, regression analysis and correlations whereas Minitab was used only for simpler regressions and correlations.

The analysis of variance used was a randomized complete block (RCB) design using the SPSS MANOVA subprogramme.

No transformations were necessary and due to the experimental design orthoganal contrasts could not be done. Differences between treatment means were examined using least significant difference (lsd).

Unless otherwise stated, significance and non significance in this thesis refers to the 5% level of probability. The symbols used throughout this thesis are: ns = not significant ($P>0.05$); $P<0.05$ (*), $P<0.01$ (**) and $P<0.001$ (***) mean significance at the 5%, 1% and 0.1% levels of probability respectively. Values with the same letter are not statistically significant ($P<0.05$).

CHAPTER 4 RESULTS

In this chapter only the most relevent results are included in the text. Other tables of means with relevent statistics are presented in Appendices 3 and 4.

The results of the intensity and frequency comparisons are presented together and statistics relate to all 6 treatments except where otherwise stated. However, during the treatment period M21 plots were not grazed on days 27/28 or 55/56. The data and relevent statistical analysis of M21 plots comes from grazings on days 20/21 and 62/63.

4.1 HERBAGE MASS

Figure 4.1 shows the effects of grazing frequency and intensity on changes in the main herbage mass components over the treatment (before the vertical line: day 83) and post-treatment (after the vertical line) periods.

For simplicity, means for these herbage mass components immediately before grazing on days 27, 55, 83, 119 and

Figure 4.1 Effect of grazing frequency and intensity on herbage mass components (kgDM/ha).

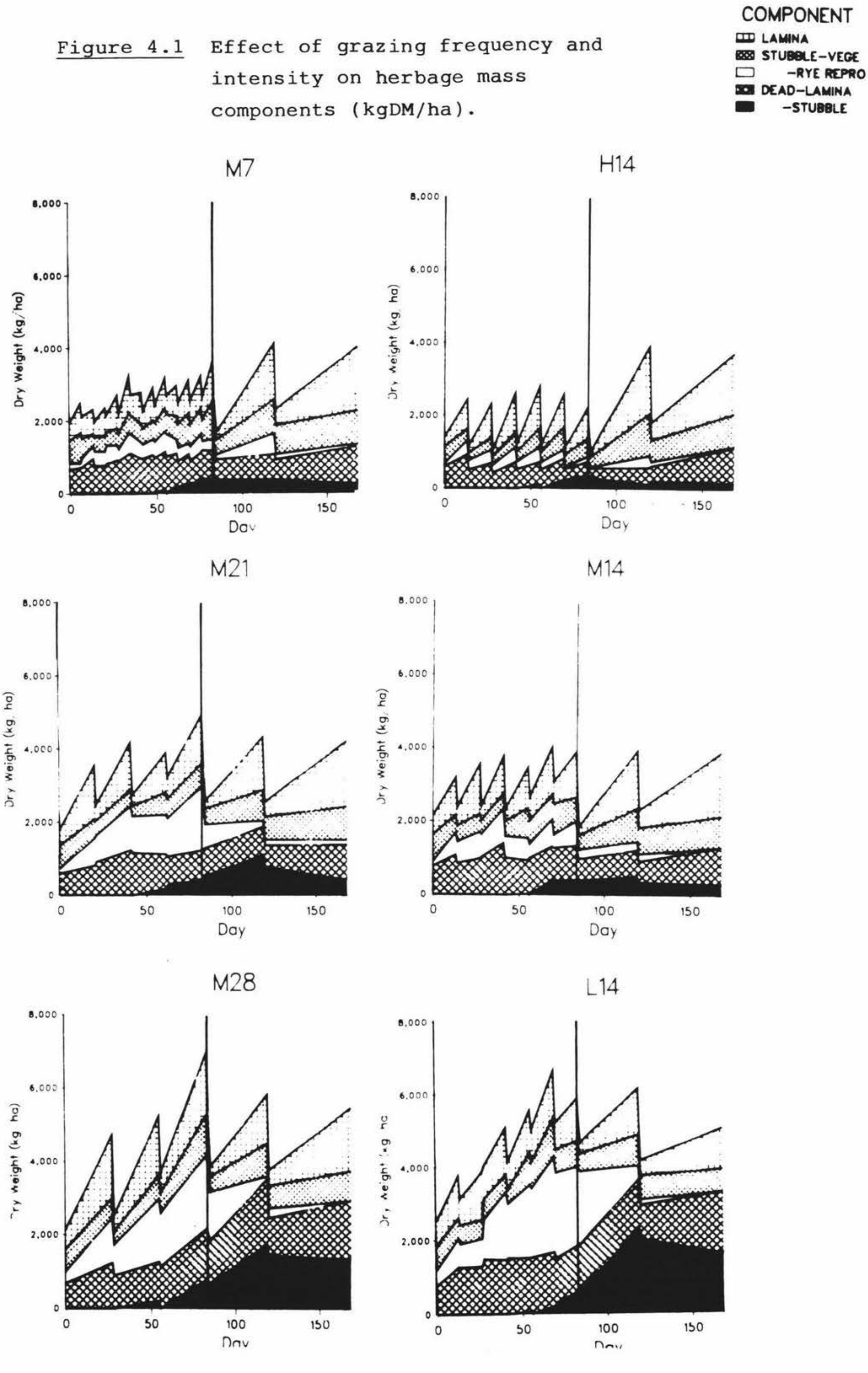


Table 4.1 **Pregrazing Herbage Mass Components on days 27, 55, 83, 119 and 168** (kgDM/ha).

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Lamina							
27	940 a	1380 b	1320 c	900 a	1380 b	1470 bc	1720 c
55	1170 b	1110 ab	1150 b	830 a	1110 ab	1230 b	1630 c
83	841 a	1234 ab	1224 ab	1085 ab	1234 ab	1307 bc	1684 c
119	1852 a	1564 a	1281 a	1538 a	1564 a	1446 a	1364 a
168	1660 b	1737 b	1111 a	1757 b	1737 b	1781 b	1732 b
b) Reproductive Stubble							
27	360 a	720 bc	750 c	420 ab	720 bc	750 c	1230 d
55	400 a	600 ab	1990 c	560 ab	600 ab	1340 bc	1720 c
83	143 a	663 a	2302 b	324 a	663 a	1727 b	2008 b
119	323 a	235 a	369 a	572 a	235 a	156 a	71 a
168	33 a	0 a	0 a	63 a	0 a	128 a	0 a
c) Vegetative Stubble							
27	360 a	500 a	530 a	460 a	500 a	530 a	540 a
55	530 a	830 a	890 a	640 a	830 a	700 a	650 a
83	507 a	654 a	745 a	1052 b	654 a	650 a	1130 b
119	1168 a	913 a	854 a	948 a	913 a	845 a	909 a
168	900 a	857 a	630 a	930 a	857 a	913 a	817 a
d) Dead Stubble							
27	0 a	0 a	0 a	0 a	0 a	0 a	0 a
55	90 a	30 a	50 a	130 a	30 a	220 a	200 a
83	344 a	411 a	607 ab	269 a	411 a	433 a	769 b
119	123 a	500 ab	2275 c	379 ab	500 ab	1105 bc	1735 bc
168	168 a	292 a	1594 b	248 a	292 a	426 a	1352 b

Table 4.1 (continued)

Day	Intensity H14		M14		L14		Frequency M7		M14		M21		M28	
e) Dead Leaf														
27	690	a	970	ab	1280	c	910	a	970	ab	810	a	1230	bc
55	630	a	910	a	1450	a	1020	a	910	a	1150	a	1060	a
83	390	a	935	b	1335	c	903	b	935	b	793	ab	1402	c
119	464	a	725	a	1338	b	692	a	725	a	780	a	1811	c
168	976	a	1007	a	1673	b	1033	a	1007	a	963	a	1605	b
f) Green Herbage														
27	1650	a	2600	b	2600	b	1790	a	2600	b	2750	b	3500	c
55	2100	a	2530	a	4030	c	2030	a	2530	a	3270	b	4000	c
83	1490	a	2550	b	4270	d	2460	b	2550	b	3680	c	4820	d
119	3340	a	2710	a	2500	a	3060	a	2710	a	2450	a	2330	a
168	2590	b	2590	b	1740	a	2750	b	2590	b	2820	b	2550	b
g) Total Herbage														
27	2340	a	3570	b	3880	b	2700	a	3570	b	3550	b	4730	c
55	2830	a	3470	a	5540	c	3170	a	3470	a	4640	b	5260	bc
83	2225	a	3897	b	6213	d	3633	b	3897	b	4910	c	6993	d
119	3930	a	3937	a	6117	b	4130	a	3937	a	4332	a	5872	b
168	3737	a	3893	a	5008	bc	4031	a	3893	a	4211	ab	5506	c

168, and some components after grazing on days 28, 56, 85 and 120, together with levels of significance are presented in Tables 4.1 and 4.2 respectively.

4.1.1 Total

Significant differences in both pre- and post-grazing total herbage mass within the intensity comparisons were established by day 27 and maintained throughout the experiment (Figure 4.1, Tables 4.1g and 4.2d). During the treatment period the total pregrazing herbage mass of the lax grazed (L14) plots increased to 2.8 times that of the hard grazed (H14) plots by day 83. The moderate grazed (M14) plots had intermediate levels of total pregrazing herbage mass which were 1.8 that of H14 by day 83. Differences between H14 and M14 quickly disappeared in the post-treatment period, but L14 was still 34% higher than H14 by the end of the experiment (day 83). Differences in post-grazing herbage mass between treatments (Table 4.2d) were generally greater than pregrazing differences.

Within the frequency comparison, there were no differences in either pre- or post-grazing total mass between M7 and M14 except on day 27. However, differences between M21 and M28 and the other treatments quickly developed and by day 83 total pregrazing herbage mass of these treatments

Table 4.2 Selected Post-grazing Herbage Mass Components on days 28, 56, 85 and 120 (kgDM/ha).

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Lamina							
28	160 a	400 b	900 c	530 b	400 b	420 b	440 b
56	170 a	650 bc	880 c	520 b	650 bc	590 b	550 b
85	140 a	240 a	310 a	220 a	240 a	220 a	270 a
120	490 a	480 a	410 a	430 a	480 a	400 a	430 a
b) Reproductive Stubble							
28	210 a	620 b	1090 c	330 a	620 b	730 b	840 b
56	190 a	370 a	1880 d	620 ab	370 a	1050 bc	1470 cd
85	20 a	250 a	1960 d	130 a	250 a	650 b	1320 c
120	130 a	200 a	140 a	140 a	200 a	150 a	260 a
c) Green Herbage							
28	630 a	1390 a	2540 c	1300 b	1390 b	1560 b	1640 b
56	680 a	1680 b	3480 d	1680 b	1680 b	2160 c	2560 c
85	450 a	890 a	2750 e	760 ab	890 b	1310 c	2020 d
120	1210 a	1400 a	1220 a	1380 a	1400 a	1180 a	1320 a
d) Total Herbage							
28	1040 a	2410 b	4020 c	2190 b	2410 b	2470 b	2530 b
56	1200 a	2680 b	5000 d	2690 b	2680 b	3230 b	3680 c
85	1010 a	1870 bc	4630 e	1690 ab	1870 bc	2600 c	3880 d
120	1840 a	2330 a	4140 b	2310 a	2330 a	2560 a	3790 b

were 35% and 90% greater than M7 respectively. During the post-treatment period differences between M21 and the more frequently grazed treatments quickly disappeared but M28 remained high throughout. There were no significant differences in post-grazing herbage mass until day 56 (Table 4.2d), when that of M21 and M28 were higher than M7 and M14. Differences remained on day 85 but by day 120 only M28 had higher post-grazing herbage mass.

4.1.2 Green

Changes in green herbage mass closely followed those of total herbage mass during the treatment period (Figure 4.1, Tables 4.2f and 4.2c). For example, correlations between green and total herbage mass were 0.98, 0.96 and 0.98 on days 27, 55 and 83 respectively ($P<0.001$). However, this relationship broke down during the post-treatment period (correlations for days 119 and 168 were not significant). During this period green herbage mass was a much lower and more variable component of total herbage mass (see section 4.1.5). There were no differences in pre or post grazing green herbage mass between treatments on days 119 and 120. However, on day 168 green herbage mass on L14 swards was reduced by 32% (Figure 4.1 and Tables 4.1f and 4.2c).

Throughout the trial ryegrass was the main component of green herbage mass (Appendix Table 3a: values are very similar to those presented in Figure 4.2). However the proportion of ryegrass in green herbage mass fell in swards H14, M14 and L14 from days 41 to 55 and the proportion of other grasses (mainly Poa annua) increased. The proportion of ryegrass in M7 swards progressively declined until day 83 as the proportion of white clover and other grasses increased. During the post-treatment period lower proportions of ryegrass in H14 and M7 were due to increased proportions of white clover in those swards.

4.1.3 Lamina

Within the intensity comparison pregrazing lamina mass was similar throughout the trial (Table 4.1a, Figure 4.1) with two exceptions. On day 27 and 83 lamina mass on H14 was about 30% lower (though only the former significantly) than M14 and L14. During the post-treatment period pregrazing lamina mass on L14 was reduced by at least 30% compared to H14. Significant differences in post-grazing lamina mass (Table 4.2a) within the intensity comparison were in line with treatment objectives (see section 3.2.2).

Within the frequency comparison pregrazing lamina mass throughout the treatment period was consistent with the length of spell the swards received (Figure 4.1, Table 4.1a). There were no significant differences in post-grazing lamina mass during the treatment period (Table 4.2a).

As with green herbage mass, ryegrass was the main component of lamina mass (Figure 4.2a,b). However, by day 83 there was a significantly greater level of white clover in M7 herbage mass. The proportion of white clover was also higher in M7 and H14 at day 168. There were no differences in the proportion of other grasses in lamina mass.

4.1.3.1 Ryegrass

Ryegrass vegetative lamina mass was similar in all treatments over the treatment period except for a higher lamina mass in M28 on day 83 (Table 4.3a). Therefore differences in total ryegrass lamina mass were largely due to differences in reproductive lamina mass.

Reproductive and total ryegrass lamina mass on H14 was lower than M14 and L14 on day 27 but there were no differences within the intensity comparison on days 55 and

Table 4.3 Vegetative, Reproductive and Total Pregrazing Ryegrass Lamina Mass (kgDM/ha) on days 27, 55, 83, 119 and 168

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Vegetative							
27	580 a	700 a	560 a	510 a	700 a	735 a	740 a
55	790 a	690 a	630 a	590 a	690 a	880 a	990 a
83	690 a	930 a	970 a	730 a	930 a	980 a	1390 b
119	1580 a	1440 a	1180 a	1220 a	1440 a	1350 a	1280 a
168	1460 b	1660 b	1010 a	1500 b	1660 b	1660 b	1660 b
b) Reproductive							
27	260 a	520 b	650 bc	230 a	520 b	570 b	840 c
55	210 ab	190 ab	310 bc	90 a	190 ab	220 ab	430 c
83	60 ab	210 bc	120 abc	30 a	210 bc	200 bc	220 c
119	60 a	40 a	0 a	110 a	40 a	0 a	30 a
168	30 a	0 a	0 a	10 a	0 a	20 a	0 a
c) Total							
27	850 a	1220 b	1210 b	740 a	1220 b	1300 b	1580 c
55	1000 b	890 ab	940 ab	680 a	890 ab	1100 b	1420 c
83	750 a	1140 ab	1100 ab	760 a	1140 ab	1190 b	1610 c
119	1640 a	1470 a	1180 a	1330 a	1470 a	1350 a	1310 a
168	1490 b	1660 b	1010 a	1510 b	1660 b	1680 b	1660 b

83(Table 4.3b,c). Within the frequency comparison reproductive ryegrass lamina mass on days 27 and 55 increased with greater spells between grazing (Table 4.3b,c). On day 83 only M7 had lower reproductive lamina mass, and higher total ryegrass lamina mass of M28 was solely due to higher vegetative lamina mass.

During the post-treatment period ryegrass lamina mass was significantly reduced only in L14 swards on day 168 (Table 4.3c) as a result of lower vegetative lamina mass (Table 4.3a).

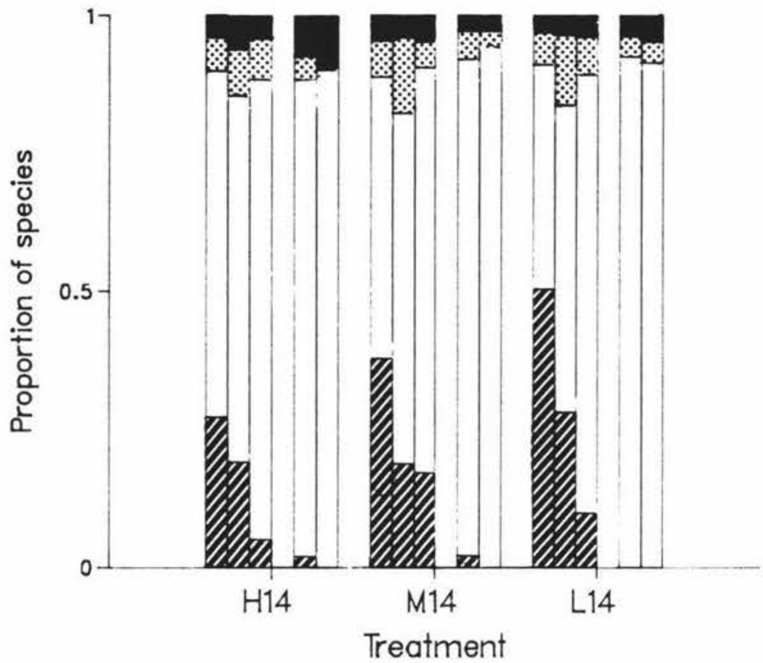
Over the treatment period the contribution of reproductive tillers to ryegrass lamina mass declined. Vegetative lamina contributed 47-71% of total ryegrass lamina on day 27 but by day 83 contributed 82-96% of total ryegrass lamina mass (Figure 4.2). The proportion of vegetative lamina mass on M7 during the treatment period was always greater than on M14, M21 and M28. It was also similar to H14 which had a higher proportion than M14 and especially L14. By day 119 there were no differences between treatments.

4.1.3.2 White Clover and Other Grasses

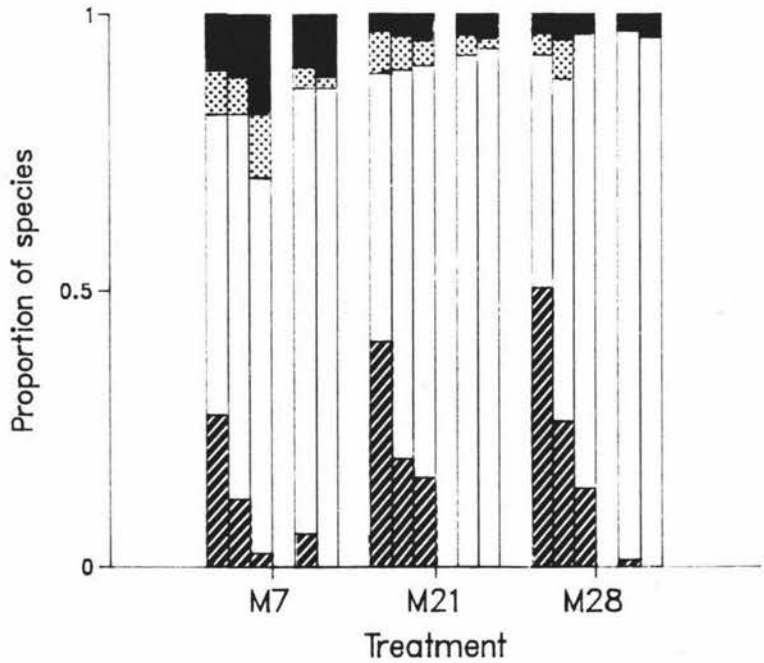
There were no differences between treatments in white clover lamina mass on days 27 and 55 (Appendix Table 3d)

Figure 4.2 Proportion of Ryegrass, White Clover and Other Grass Lamina in Total Pregrazing Lamina Mass*.

a) Intensity

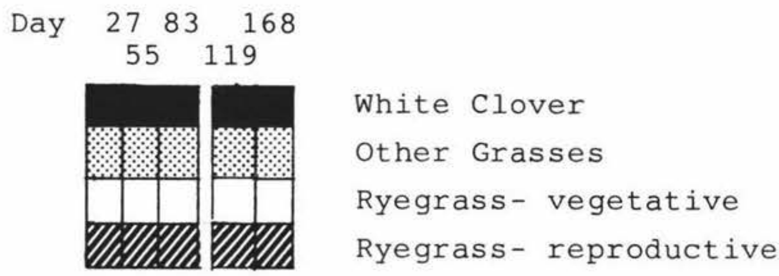


b) Frequency



* See Appendix Table 3b for statistical analysis

Figure 4.2 Key



but by day 83 white clover lamina mass was significantly greater on M7 swards (Table 4.4).

During the post-treatment period there were no differences in white clover lamina mass on day 119 (Appendix Table 3d) but on day 168 both M7 and H14 had higher lamina mass than all other treatments.

At no time were there any differences between treatments in other grass lamina mass (Appendix Table 3c).

4.1.3.3 Proportion of Lamina in herbage mass

The proportion of lamina in herbage mass was calculated in two ways. The first, Leaf:Stem (L:S) ratio describes the proportion of lamina in green herbage mass and the second, Leaf:Non-Leaf (L:NL) ratio, describes the proportion of lamina in total (lamina, stubble and dead) herbage mass.

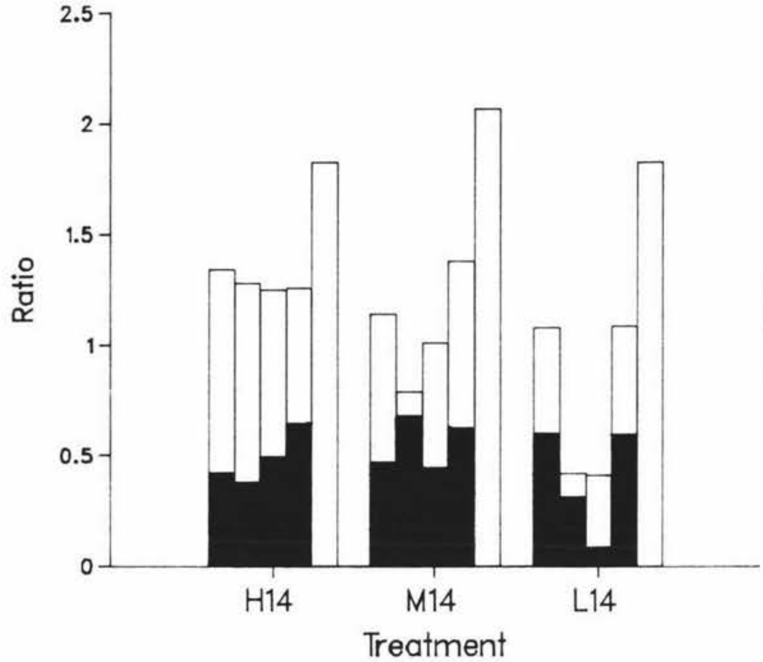
Pre- and post-grazing L:S ratios are given in Figure 4.3. Pregrazing L:S ratio on H14 remained high throughout the treatment period whereas it had declined in M14 and especially L14 by day 55 (Figure 4.3a). L:S ratio on M14 had recovered somewhat by day 83 but remained significantly lower on L14.

Table 4.4 **White Clover a) Pregrazing Lamina Mass (kgDM/ha) and b) Stolon tip density (numbers/m^2) on days 83 and 168**

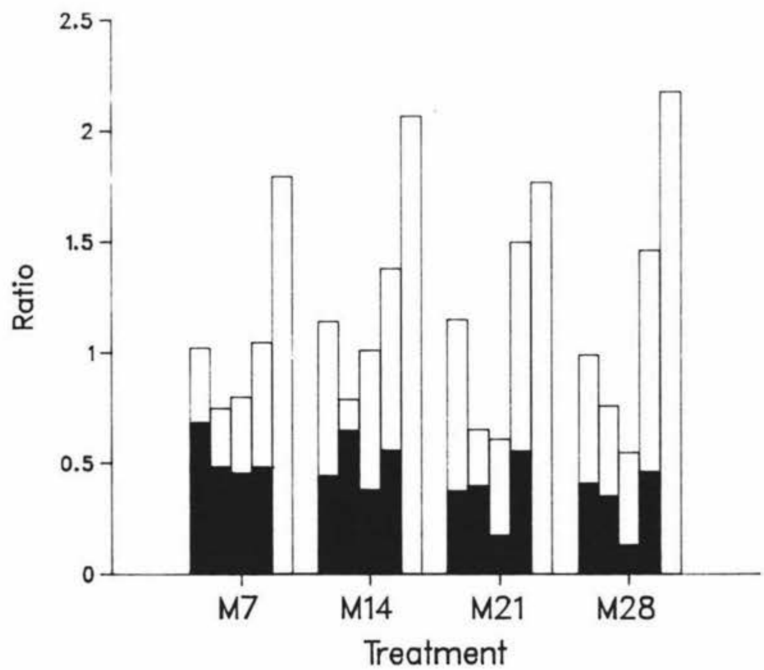
	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Lamina Mass							
83	30 a	50 a	60 a	220 b	50 a	70 a	50 a
168	160 bc	50 a	80 ab	210 c	50 a	90 ab	60 a
b) Stolon Tip Density							
83	510 a	710 a	1050 a	5790 b	710 a	790 a	40 a
168	1040 bc	320 a	290 a	1330 c	320 a	450 ab	250 a

Figure 4.3 Pre- and Post-Grazing Leaf:Stem (L:S) Ratio on days 27/28, 55/56, 83/85, 119/120 and 168*.

a) Intensity



b) Frequency



* See Appendix Table 3e for statistical analysis

Key to Figure 4.3

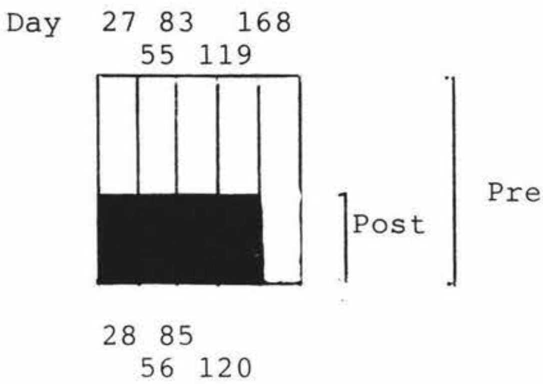
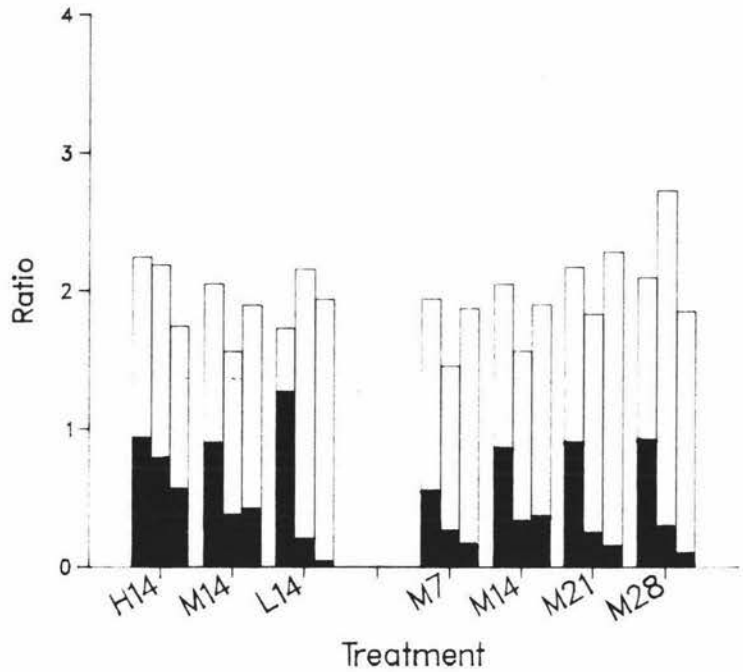


Figure 4.4 Leaf:Stem (L:S) Ratio on Vegetative and Reproductive Ryegrass Tillers on days 27, 55 and 83.



Key

Day 27 55 83

ns .49 ns SED (vegetative)

ns 0.15 SED (reproductive)

Post-grazing L:S ratio was similar or higher on M14 compared with H14 but on L14 plots it declined throughout the treatment period to be significantly lower than H14 and M14 by day 83.

Within the frequency comparison (Figure 4.3b) there were no significant differences in pregrazing L:S ratio during the treatment period except on day 83 when less frequently grazed (M21 and M28) swards had lower L:S ratios than M7 or M14.

Differences in post-grazing L:S ratio were apparent from day 27 (Appendix Table 3e) and by day 83 that of M7 and M14 were much greater than M21 and M28.

During the post-treatment period pregrazing L:S ratios increased substantially and there were no significant differences in either pre- or post- grazing L:S ratios.

Differences in L:S ratio were largely due to differences in the L:S ratio of ryegrass reproductive tillers as differences in the L:S ratio of vegetative tillers were generally small or inconsistent (Figure 4.4). However, L:S ratios on vegetative tillers tended to increase with reduced grazing frequency especially on day 55. L:S ratios on vegetative tillers were generally about 2.0 whereas on reproductive tillers L:S ratios fell from about 0.7 to about 0.3 during the treatment period.

On day 27 reproductive tiller L:S ratios were greater on L14 than M14 and H14. However by day 55 this was reversed and L14 had significantly lower L:S ratios than M14 and especially H14, and remained so on day 83.

Reproductive tiller L:S ratios did not differ with grazing frequency. However, M14 reproductive tillers had greater L:S ratio than other treatments on day 83.

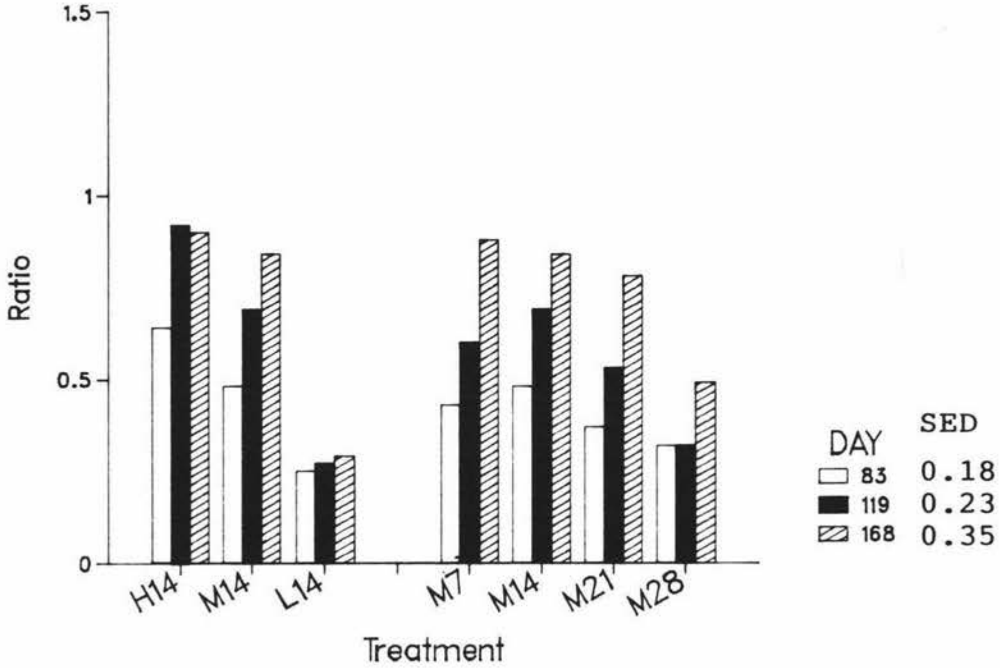
There were no differences in L:S ratio during the post-treatment period (Figure 4.3). However, there were large differences in Leaf:Non-leaf ratios during this period (Figure 4.5). On both days 119 and 168 Leaf:Non-leaf ratios were significantly reduced on swards L14 and M28.

4.1.4 Stubble

Differences between treatments in stubble mass were mostly due to ryegrass reproductive stubble as differences in vegetative (vegetative ryegrass, white clover and other grass) stubble were small and inconsistent (Table 4.1c, Figure 4.1).

During the treatment period differences in pre- and post-grazing ryegrass reproductive stubble were apparent

Figure 4.5 Leaf:Non-leaf Ratio on days 83, 119 and 168.



by day 27, though it was between days 27 and 55 that the most rapid increases in reproductive stubble mass took place (Figure 4.1, Tables 4.1b and 4.2b). Pregrazing reproductive stubble mass of L14 was at least 4 times greater than M14 and H14 on both days 55 and 83. Similarly, the pregrazing reproductive stubble mass of M21 and M28 had increased to at least 3.5 times that of M7 and M14 by day 83.

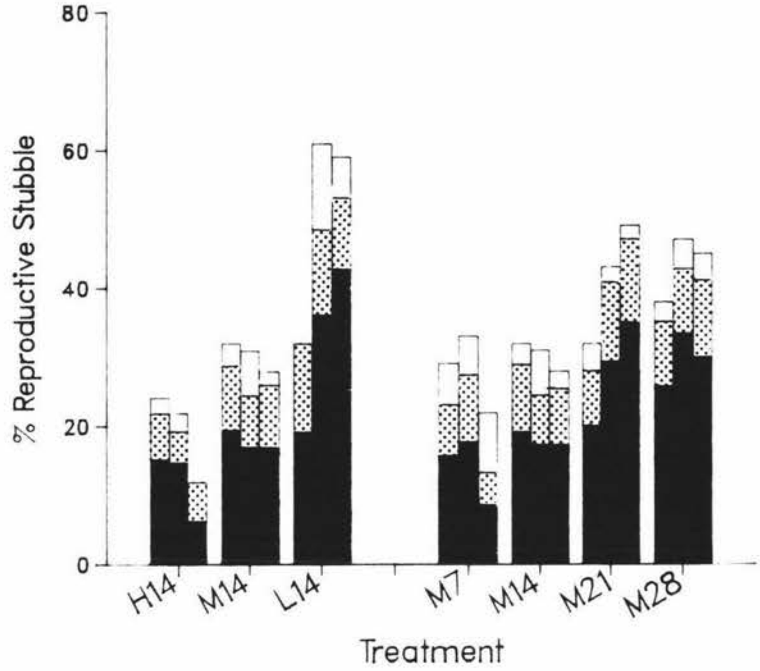
By day 119 all differences in ryegrass reproductive stubble mass between treatments had disappeared.

Differences between treatments were also reflected in the proportion of ryegrass reproductive stubble in total ryegrass herbage mass, and green and total herbage masses (Figure 4.6). Throughout the treatment period the proportion of ryegrass reproductive stubble in total, green and total ryegrass herbage mass increased with less severe and less frequent grazing. By day 83 swards L14, M21 and M28 had significantly greater proportions of reproductive stubble than swards H14, M7 and M14.

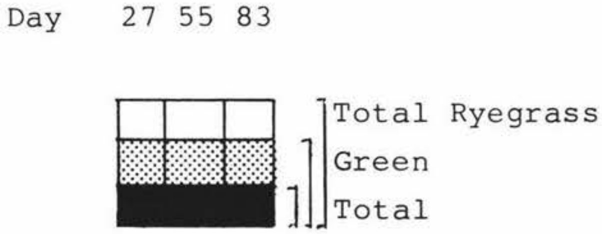
4.1.5 Dead

Over the experimental period dead herbage consisted of

<u>Figure 4.6</u> **Percentage Ryegrass Reproductive Stubble Mass in Total Ryegrass, Green and Total Herbage Masses on days 27, 55 and 83*.**



<u>Key</u>



* see Appendix Table 3f for statistical analysis

both dead ryegrass reproductive stubble and other dead herbage (ryegrass lamina and vegetative stubble, and other species). These two catagories are, for simplicity, designated and dead 'stubble' and dead 'leaf' respectively in Figure 4.1 and Tables 4.1d,e.

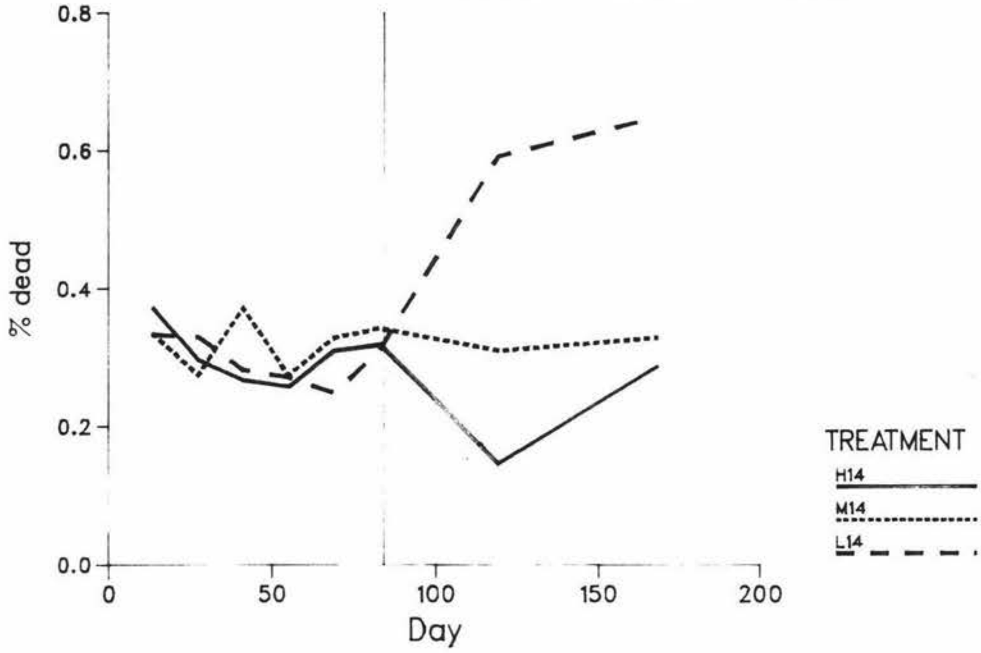
Within the intensity comparison dead leaf in M14 was 2.4, and in L14 3.4, times that of H14 by day 83 (Figure 4.1, Table 4.1d). Within the frequency comparison dead leaf on M28 was at least 50% greater than the other treatments. During the post-treatment period dead leaf on L14 and M28 remained more than 50% greater than on other treatments.

By the end of the treatment period differences in dead 'stubble' were relatively small though levels on M28 were significantly greater than on other treatments (Figure 4.1, Table 4.1d). Dead 'stubble' was not present in swards until about day 55. In all treatments at least 75% of the ryegrass reproductive stubble remaining after day 85 had died by day 119. In the intensity comparison L14 had 4.5 and 18.5 times the dead stubble on M14 and H14 respectively on day 119; and at least 5.5 times the dead stubble on M14 and H14 on day 168. In the frequency comparison M21 and M28 had much greater levels (at least 2.2 and 3.5 times) of dead stubble on day 119 than M7 and M14 (n.s.), but by day 168 only M28 still had significantly greater amounts of dead stubble than the other treatments.

Figure 4.7 Percentage Dead Herbage Mass in Total Pregrazing Herbage Mass.

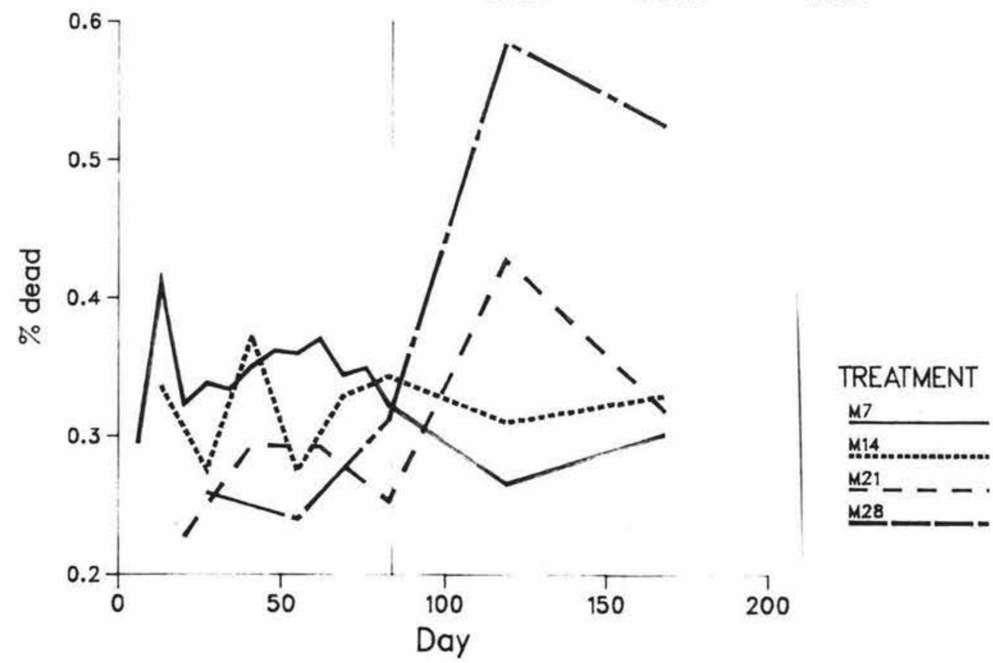
a) Intensity

ns	ns	ns	***	***	Significance
			0.05	0.05	SED



b) Frequency

ns	ns	ns	***	***	Significance
			0.05	0.05	SED



There were no differences in the proportion of dead herbage in the swards during the treatment period (Figure 4.7a,b). However there was a significantly greater proportion of dead herbage on treatments M21, M28 and L14 than treatments M7, M14 and H14 by day 119 and remained so on M28 and L14 until day 168.

4.2 TILLER (STOLON) POPULATIONS

Results of both tiller (stolon) density and individual tiller mass are presented in this section. Because correlations between estimates of population density derived from herbage dissection samples and tiller cores were high (Appendix 5), and because estimates of ryegrass reproductive tiller density were obtained only from the former, only the results from dissection samples are presented.

4.2.1 Ryegrass

4.2.1.1 Vegetative tillers

Ryegrass vegetative tiller density is given in Figure 4.8. On day 27 there were no differences between treatments in vegetative tiller density. However differences were established by day 55 and maintained until day 83. Vegetative tiller density on these days was greater with more intense (Figure 4.8a) and frequent (Figure 4.8b) grazing.

During the post-treatment period differences within the frequency comparison became smaller and finally non-significant by day 168. However the vegetative tiller density of L14 was significantly lower than M14 and H14 throughout the post-treatment period.

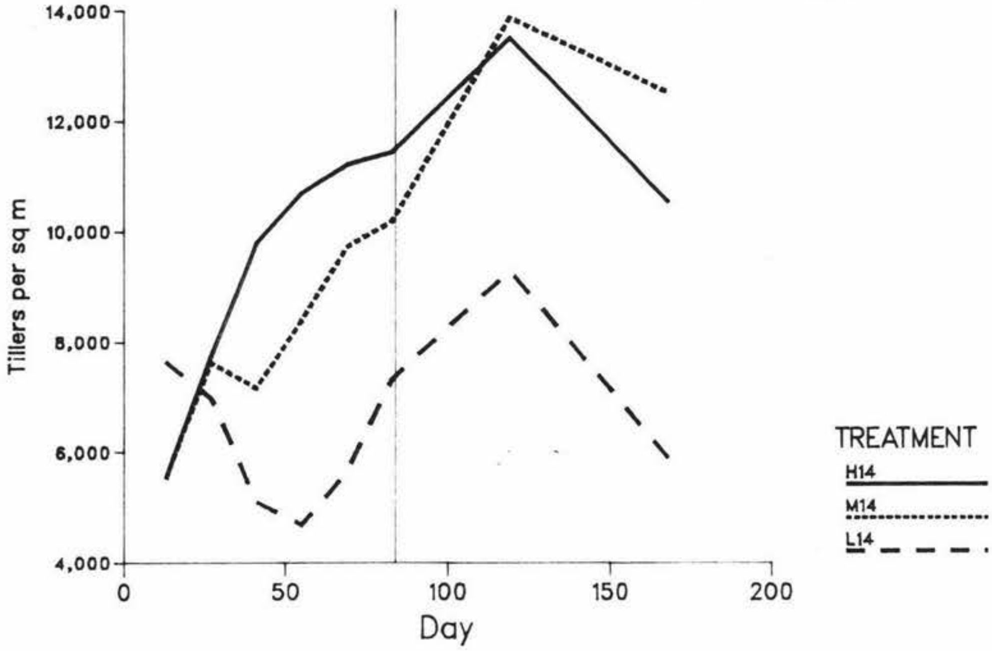
Individual vegetative tiller mass before grazing, on the other hand, was lower with more intense (Figure 4.9a) and more frequent (Figure 4.9b) grazing especially on days 55 and 83. By day 83 the individual vegetative tiller mass on L14, M21 and M28 was significantly greater than that of H14, M7 and M14. During the post-treatment period differences became smaller and by day 168 there were no significant differences although the individual vegetative tiller mass of L14 was about 40% greater than M14 and H14.

During the treatment period differences in the lamina mass of individual vegetative tillers (Figure 4.10a) were of similar magnitude to total individual pregrazing mass. Post-grazing vegetative tiller lamina mass (Figure 4.10a)

Figure 4.8 Ryegrass Vegetative Tiller Density (tillers/m^2).

a) Intensity

ns	*	*	**	*	Significance
	1476	1413	1101	1573	SED



b) Frequency

ns	*	*	**	ns	Significance
	1476	1413	1101		SED

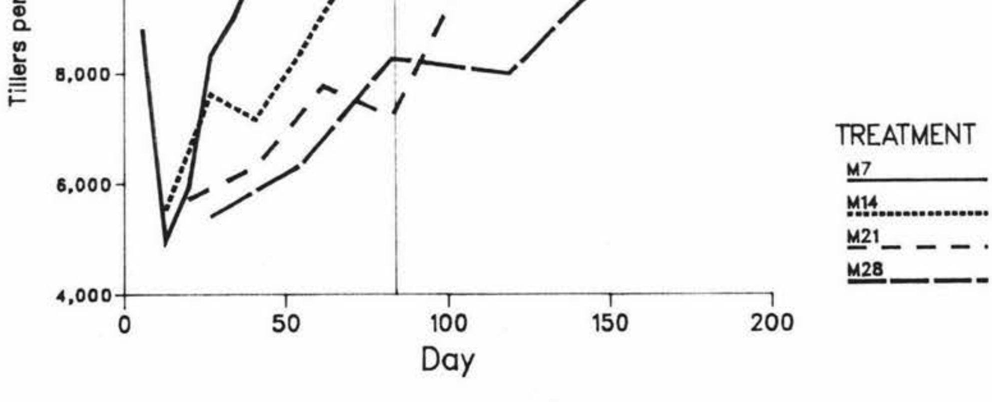
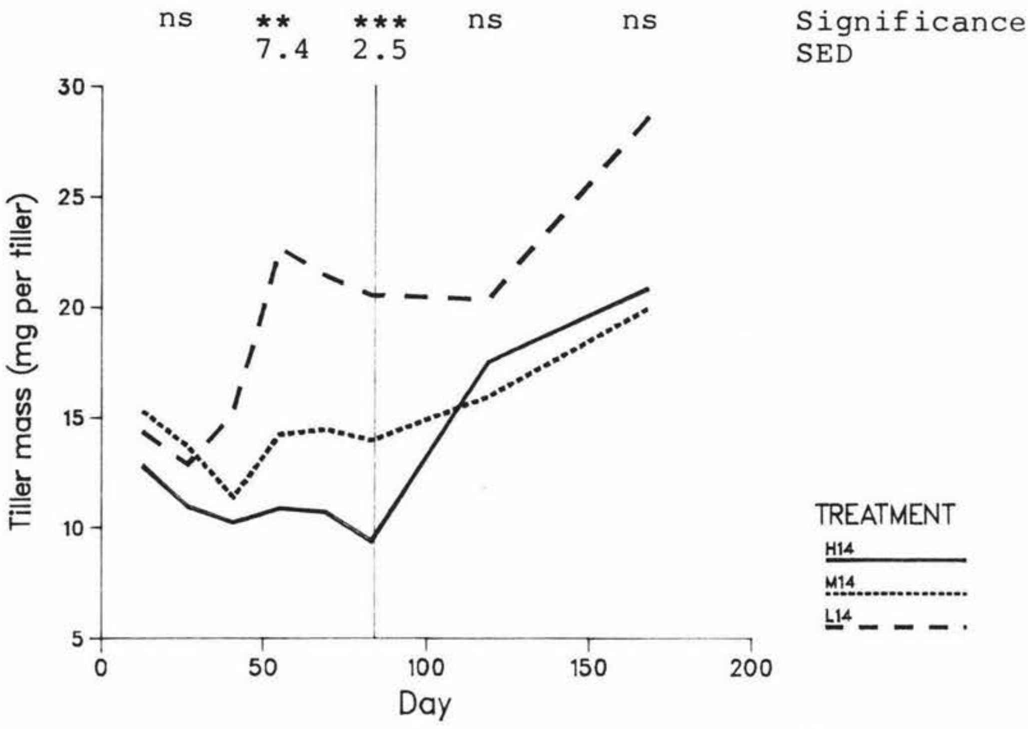


Figure 4.9 Individual Ryegrass Vegetative Tiller Mass (mg/tiller).

a) Intensity



b) Frequency

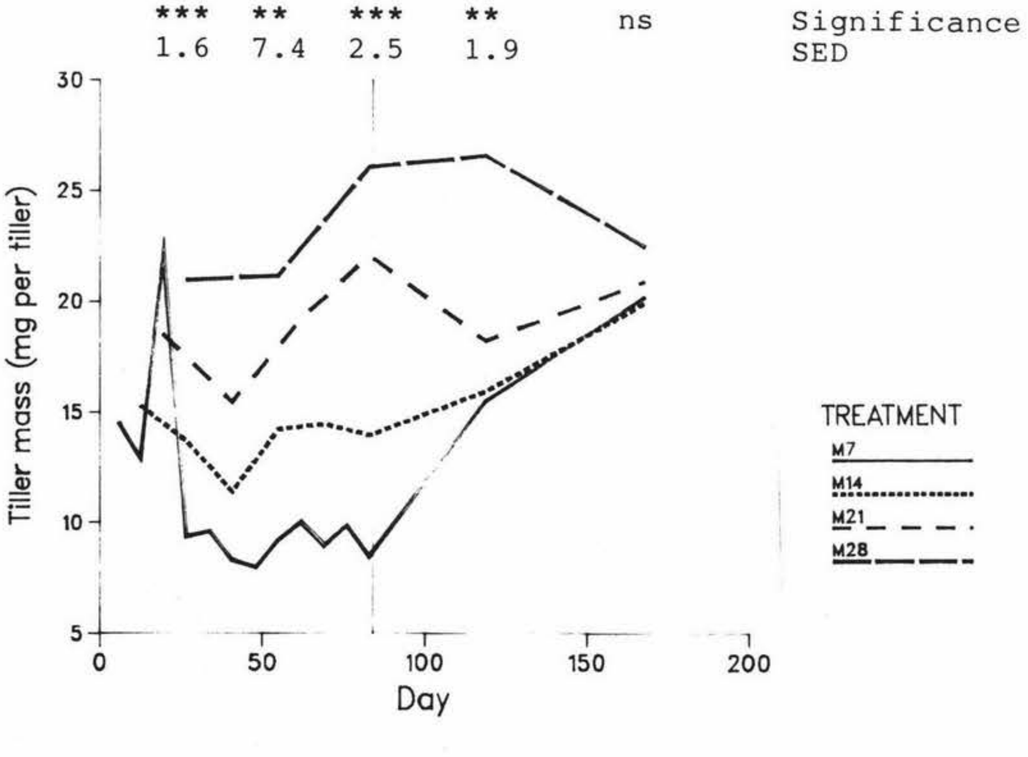
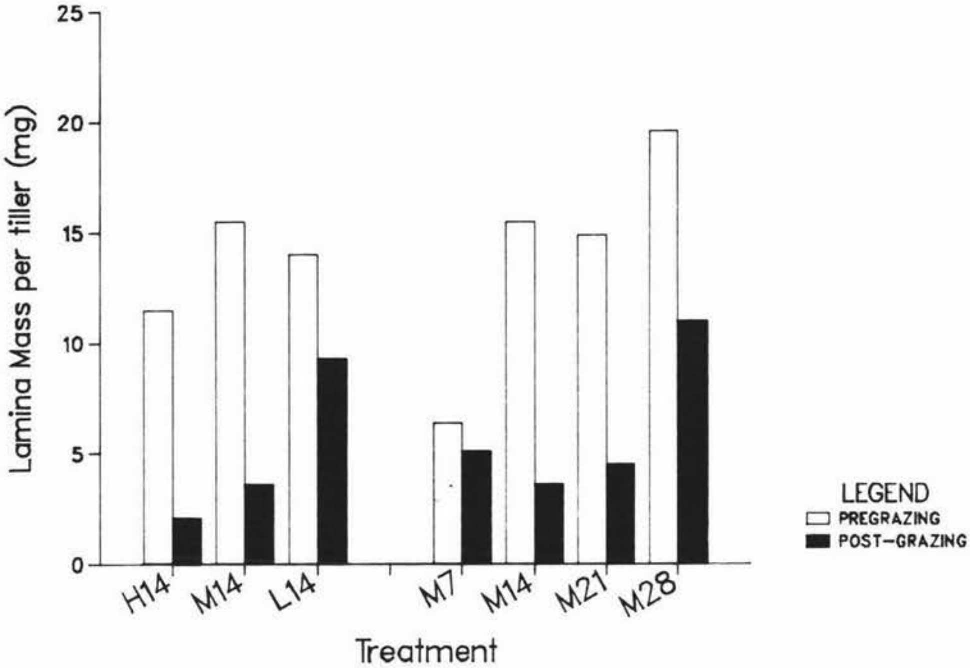
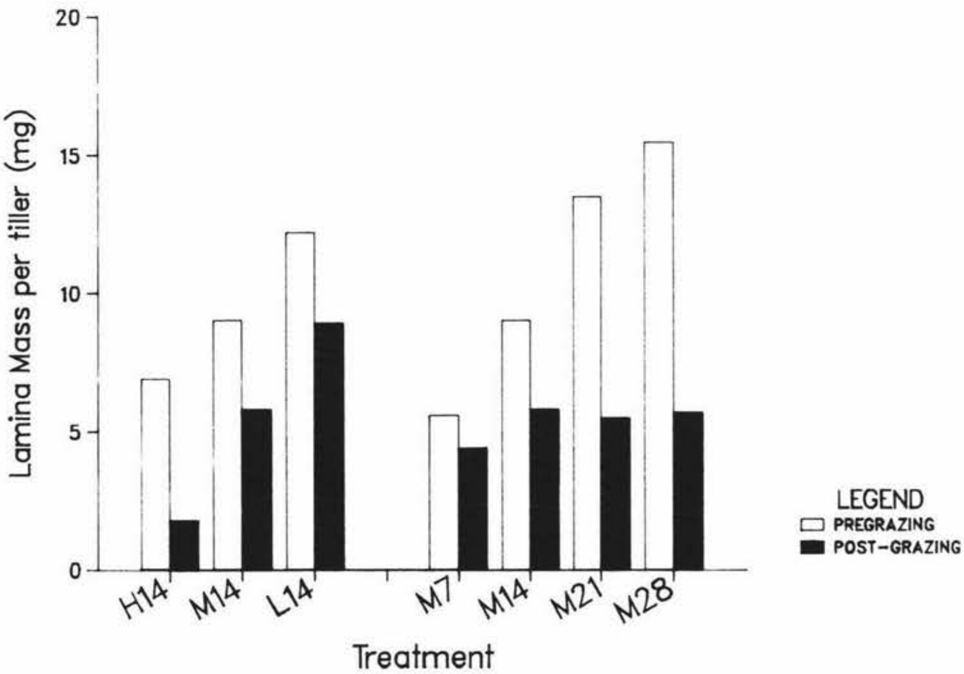


Figure 4.10 Mean Pre- and Post- Grazing Lamina Mass* of a) Vegetative and b) Reproductive Tillers over the Treatment Period**.

a) Vegetative



b) Reproductive



* Means of days 27, 55 and 83 (Pre) and days 28 and 56 (Post).

** See Appendix Table 3g for statistical analysis increased with reduced grazing intensity but was unaffected by grazing frequency during the treatment period.

4.2.1.2 Reproductive tillers

The density of undefoliated ryegrass reproductive tillers (Figure 4.11a,b) declined as the trial progressed on all treatments except M7 on which reproductive tiller density was initially low and increased to the level of the other treatments before declining. In the intensity comparison on days 27 and 55, L14 had a higher density of reproductive tillers than H14, with M14 intermediate. Differences were only significant on day 83, however, when L14 and M14 had over twice the density of reproductive tillers as H14. In the frequency comparison differences only arose in the last four weeks of the treatment period when M7 had a much lower density of undefoliated reproductive tillers (by at least 50%) than the other treatments.

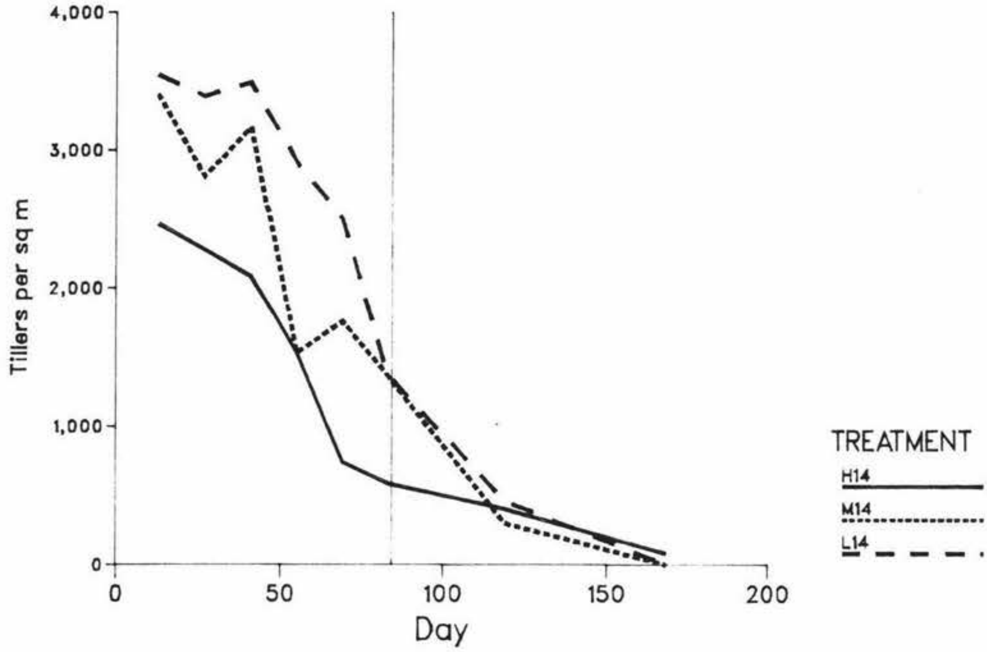
There were no differences between treatments during the post-treatment period.

The inflorescence of ryegrass reproductive tillers began emerging on about day 35 (late October/early November) and

Figure 4.11 Ryegrass Undefoliated Reproductive Tiller Density ($tillers/m^2$).

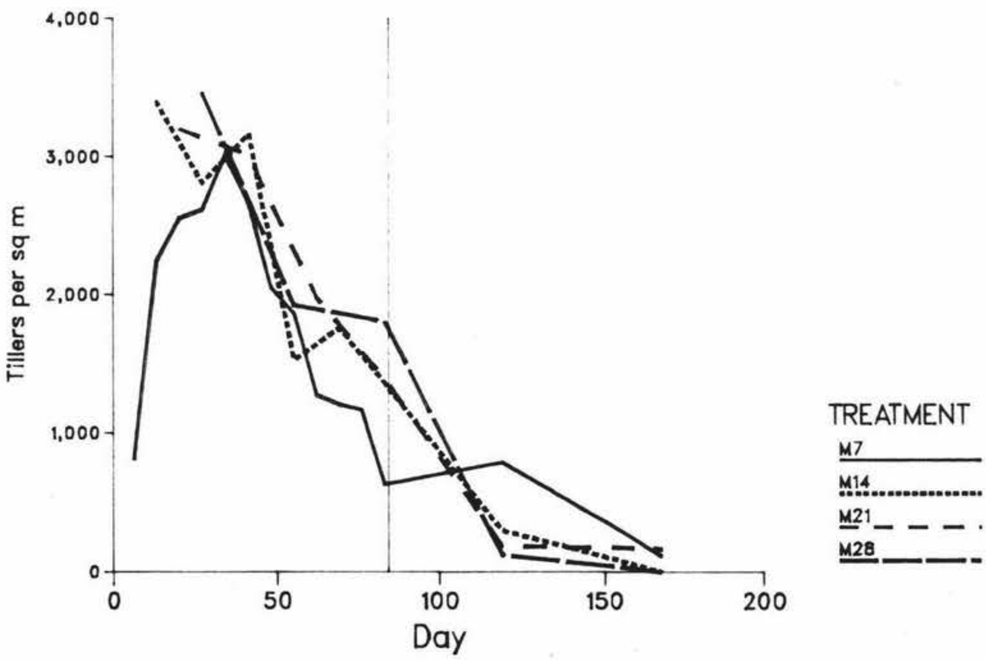
a) Intensity

	ns	ns	*	ns	ns	Significance
			287			SED



b) Frequency

	ns	ns	*	ns	ns	Significance
			287			SED



differences between treatments quickly appeared (Figure 4.12). By day 83 the emerged inflorescence density of L14 was almost twice that of any other treatment. The emerged inflorescence density of M21 and M28 were 2-3 times greater than that of M7 and M14, and H14 had virtually no emerged inflorescence at all.

Throughout the treatment period there was a greater proportion of undefoliated reproductive tillers in total ryegrass tiller density (Table 4.5) with less severe and less frequent grazing. The proportion of undefoliated reproductive tillers generally declined during the treatment period and during the post-treatment period there were no differences between treatments.

The summation of changes in undefoliated reproductive tiller density during the rest periods (Table 4.6) suggests that more reproductive tillers appeared in treatments H14 and M14 than L14, and in treatments M7 and M14 than M21 or M28. The results must be treated with some caution, however, as the standard error of the differences were very large.

Differences between treatments in individual undefoliated reproductive tiller mass were quickly established, and became increasingly greater, during the treatment period (Figure 4.13a,b). In the intensity comparison H14 and M14 individual mass was similar, but that of L14 about 3 times

<u>Figure 4.12</u> Emerged Inflorescence Density (tillers/m^2).

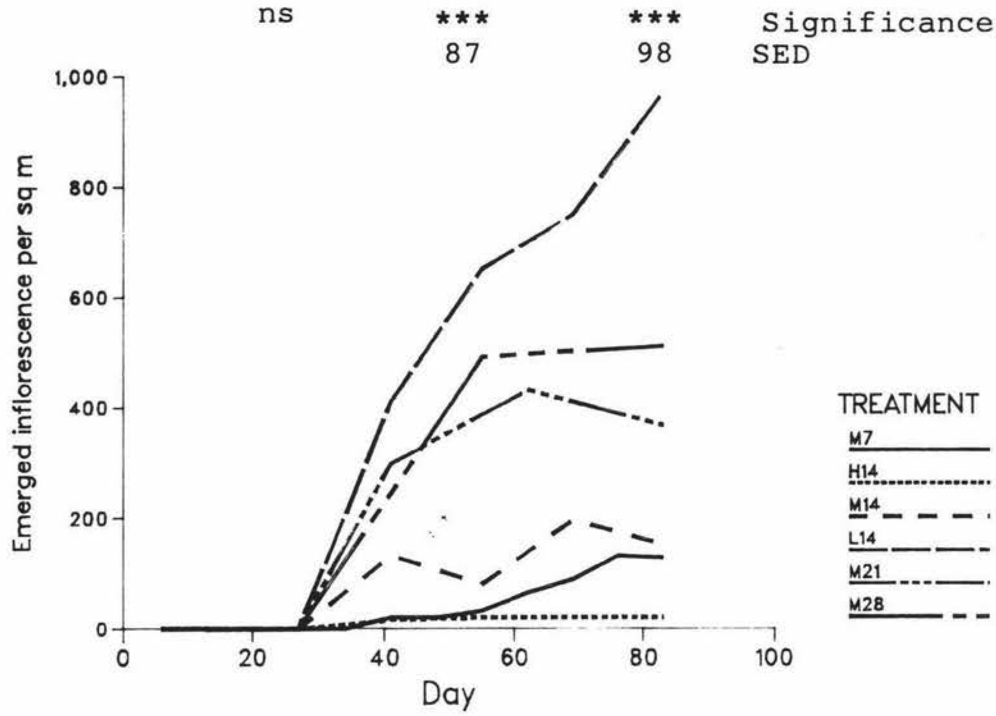


Table 4.5 **Proportion of Undefoliated Reproductive Tillers in Total Ryegrass Tiller Density on days 27, 55 and 83.**

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
27	22.6 a	27.8 ab	33.7 ab	24.6 a	27.8 ab	35.8 b	39.8 b
55	13.2 a	15.2 a	40.2 b	14.8 a	15.2 a	22.5 a	24.4 ab
83	5.1 a	12.2 ab	16.4 ab	5.0 a	12.2 ab	19.3 b	17.2 b

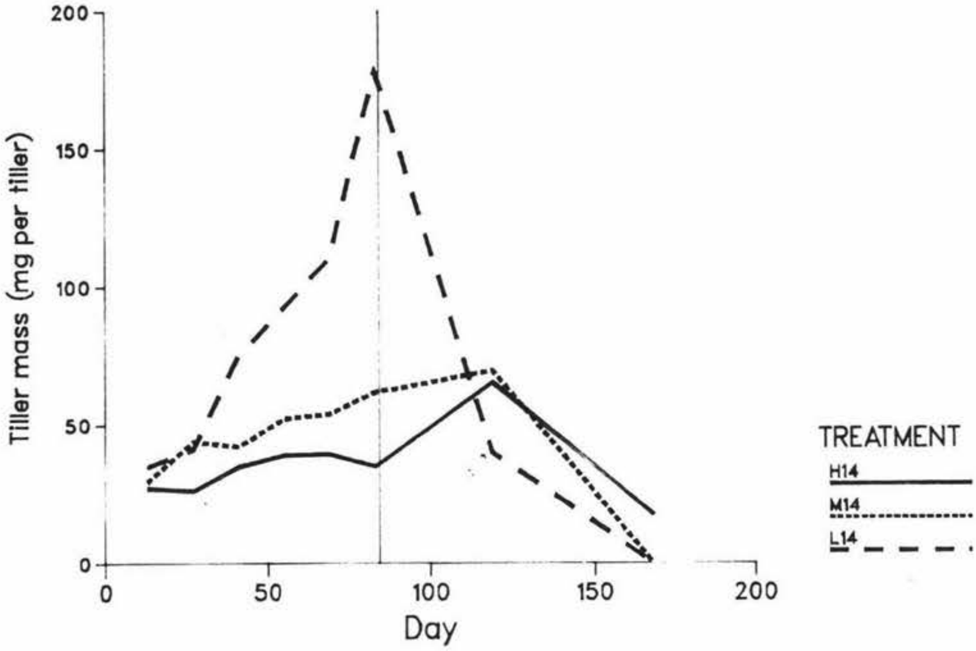
Table 4.6 Appearance of Reproductive Tillers over the Treatment Period (tillers/m^2).

	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
Initial (day 0)	594 a	782 a	2305 c	981 ab	782 a	836 ab	1907 bc
0-27	2759 a	2787 a	2080 a	1372 a	2787 a	2489 a	1623 a
28-55	1747 a	631 a	-1004 a	2045 a	631 a	140 a	-394 a
56-83	924 bc	1627 c	-1175 a	1100 bc	1626 c	-207 ab	94 abc
0-83	5430 c	5044 bc	-99 a	4517 bc	5044 bc	2422 ab	1323 a
Grand Total	6024 a	5826 a	2206 a	5498 a	5826 a	3258 a	3230 a

Figure 4.13 Individual Ryegrass Undefoliated Reproductive Tiller Mass (mg/tiller).

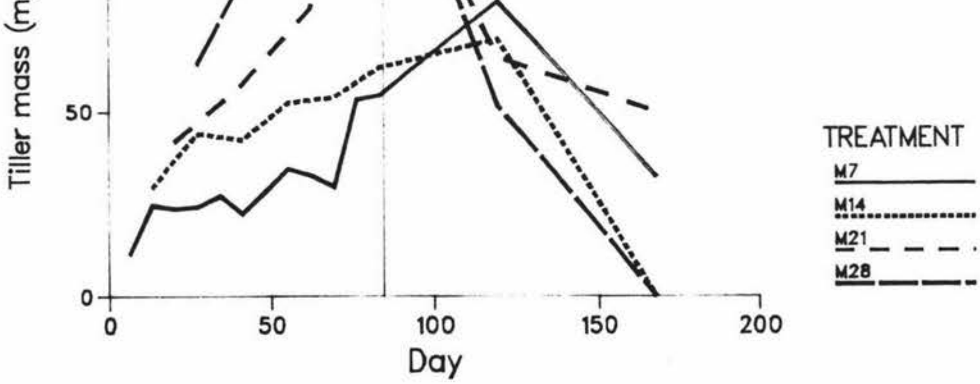
a) Intensity

** 6.6   * 18.7   *** 18.7   ns   ns   Significance SED



b) Frequency

** 6.6   * 18.7   *** 18.7   ns   ns   Significance SED



greater than the other two treatments by day 83. In the frequency comparison the individual tiller mass of M21 and M28 were more than 2 times greater than M7 and M14 by day 83.

There were no differences in individual tiller mass by day 119 of the post-treatment period.

The pregrazing lamina mass of individual reproductive tillers was very similar within the intensity comparison (Figure 4.10b) except for H14 on day 27 which was lower than M14 or L14 (Appendix Table 3g). Within the frequency comparison the pregrazing lamina mass of individual reproductive tillers increased with less frequent grazing. However differences were reduced as the treatment period progressed so that by day 83 only M7 had significantly lower lamina mass (Appendix Table 3g).

Post grazing lamina mass on individual reproductive tillers increased as grazing severity declined throughout the treatment period (Figure 4.10b). Within the frequency comparison it was higher only on M28 but by day 83 this difference had been reduced to insignificance (Appendix Table 3e).

4.2.2 White Clover and Other Grasses

During the treatment period there were no differences in white clover stolon tip density between treatments except for M7 on which stolon tip density was greater throughout the period, although differences were not significant until day 83 (Table 4.4). Over the post-treatment period both M7 and H14 had higher stolon tip density though again, this was significant only on day 168.

There were no differences in the tiller density of other grasses except M7 on day 83 which had at least twice the density of any other treatment (Appendix Table 3c).

4.3 SWARD STRUCTURE

4.3.1 Canopy Structure

By day 83 large differences in canopy structure had developed between treatments H14, M7 and M14 (Figure 4.14b,c,d) and treatments M21, M28 and L14 (Figure 4.14e,f,g). Plates 4.2b-g show these swards before the stratified cuts were done. The canopy structure on the former remained similar to that on day 0 (Figure 4.14a), whereas on the latter a greater proportion of stubble and dead herbage was found toward that top of the canopy and there was a greater intermingling of these components with

Figure 4.14a Canopy Structure immediately before the start of the trial on day 0.

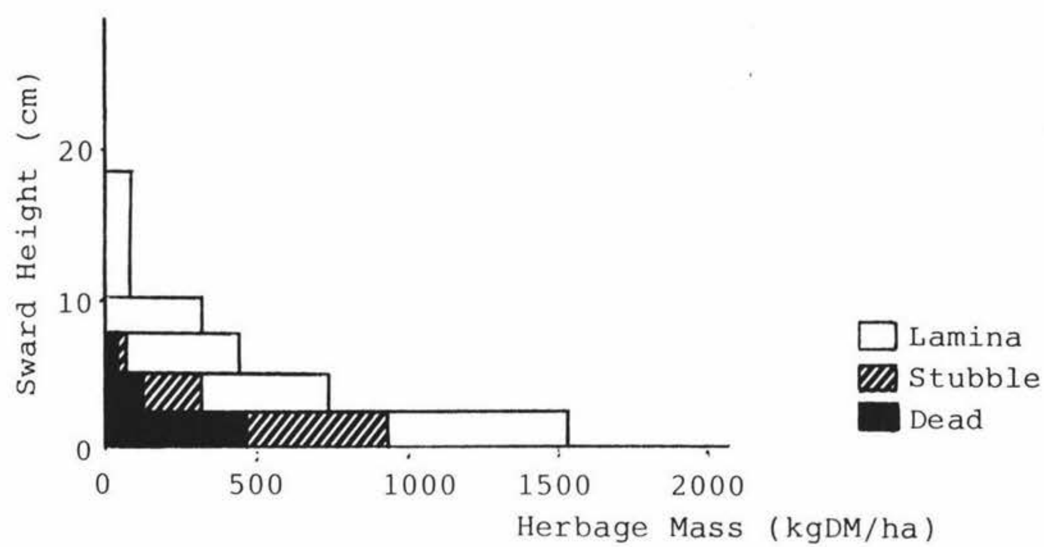


Figure 4.14b, Plate 4.1b Canopy Structure and horizon OMD and lamina bulk Density of H14 on day 83.

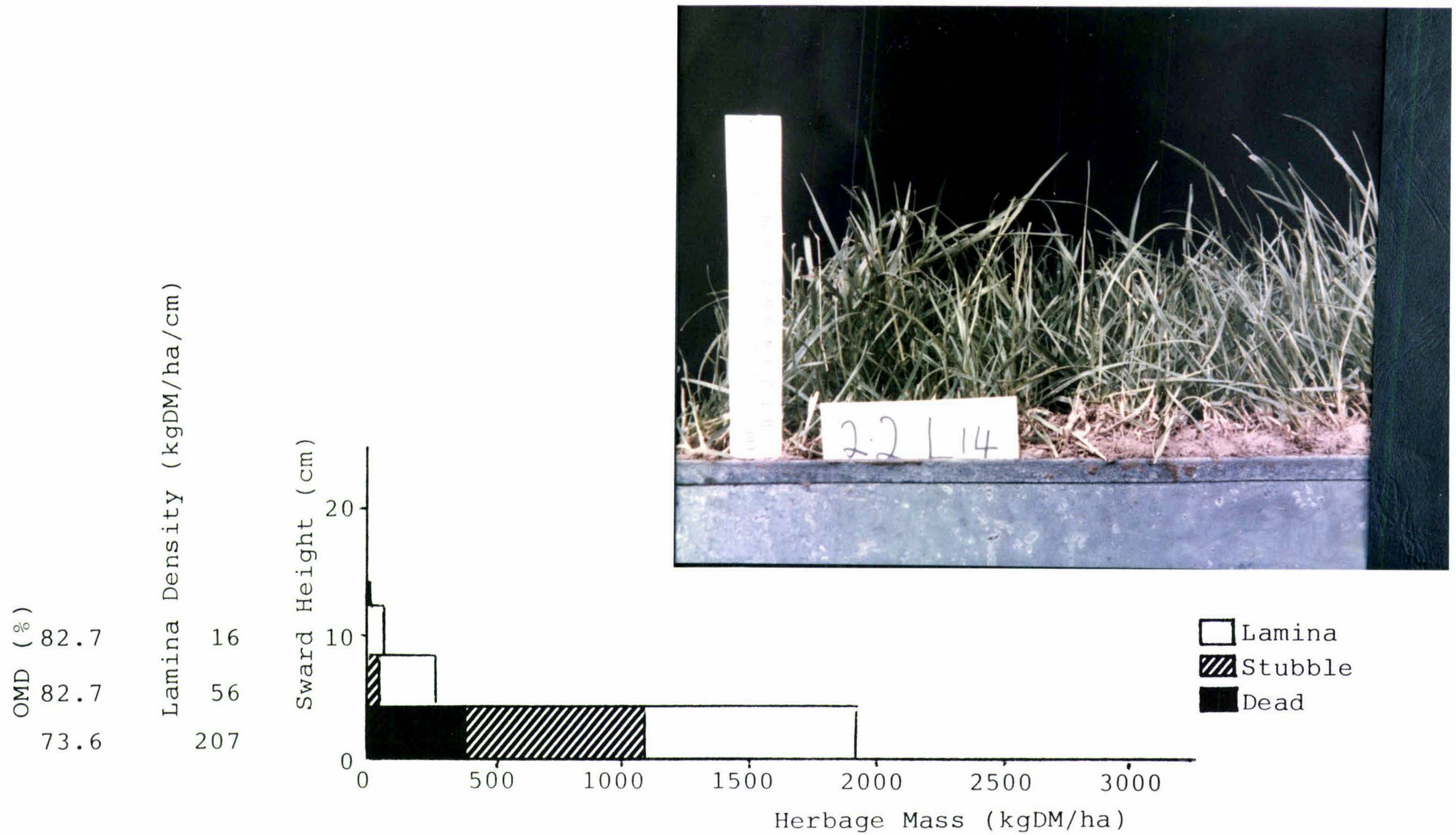


Figure 4.14c, Plate 4.1c Canopy Structure and Horizon OMD and Lamina Bulk Density of M7 on day 83.

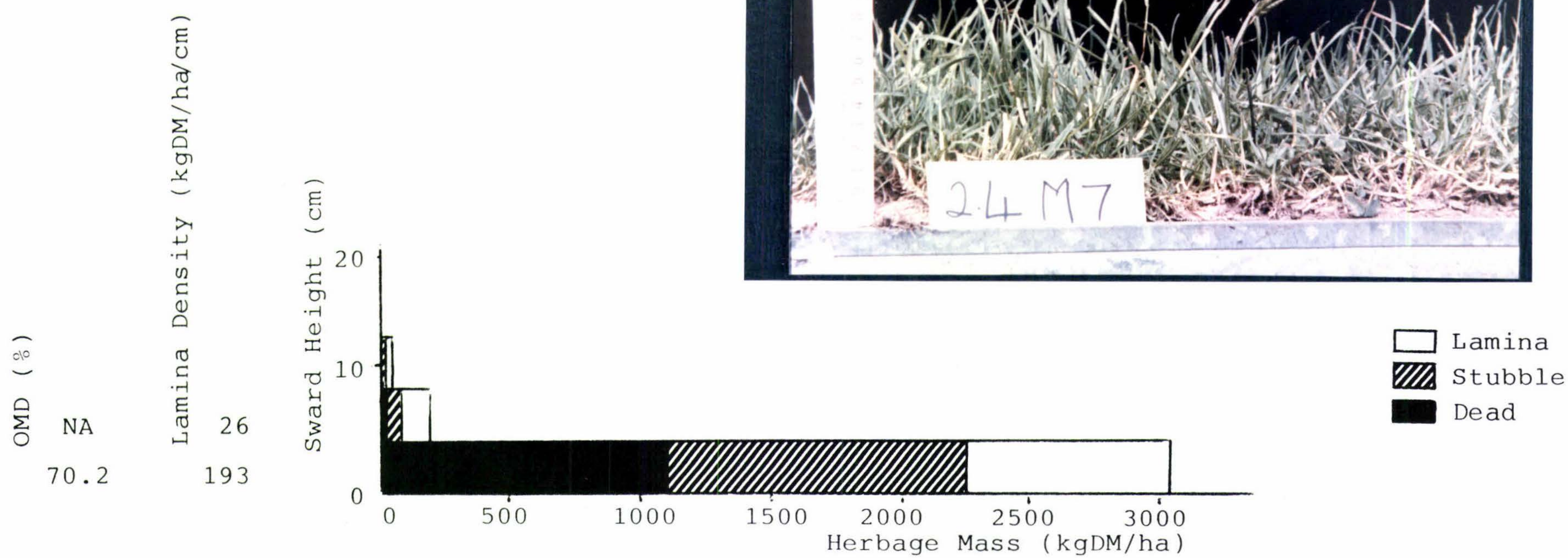


Figure 4.14d, Plate 4.1d Canopy Structure and Horizon OMD and Lamina Bulk Density of M14 on day 83.

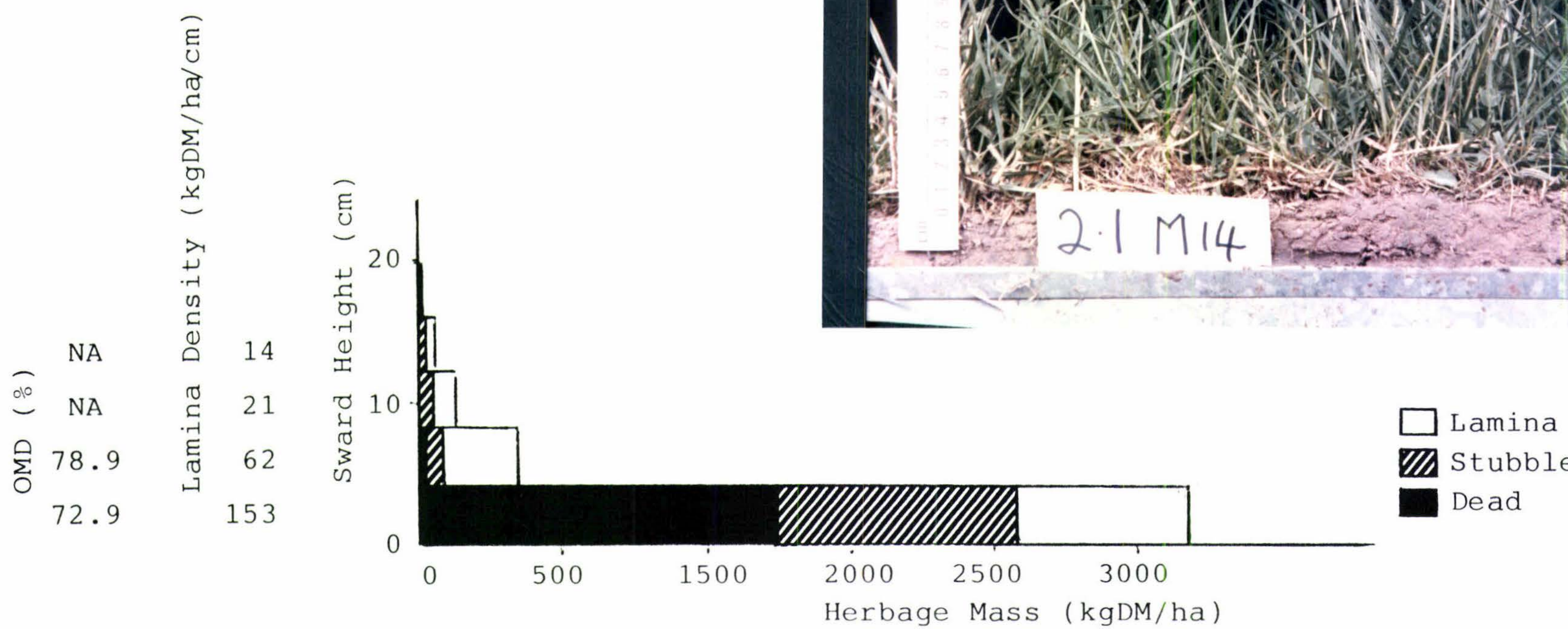


Figure 4.14e, Plate 4.1e Canopy Structure and horizon OMD and lamina bulk density of L14 on day 83.

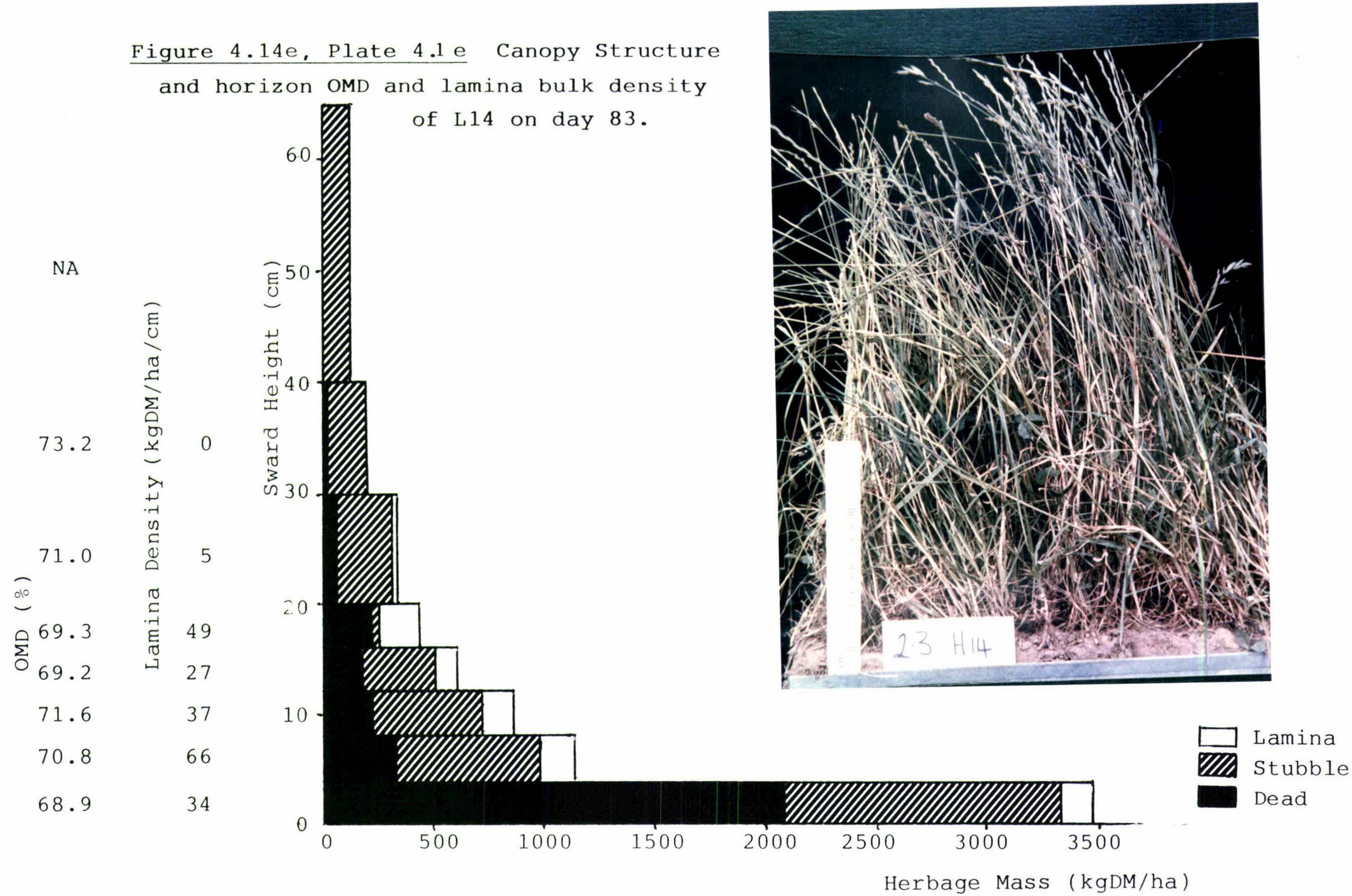


Figure 4.14f, Plate 4.1f Canopy Structure and Horizon OMD and Lamina Density of M21 on day 83.

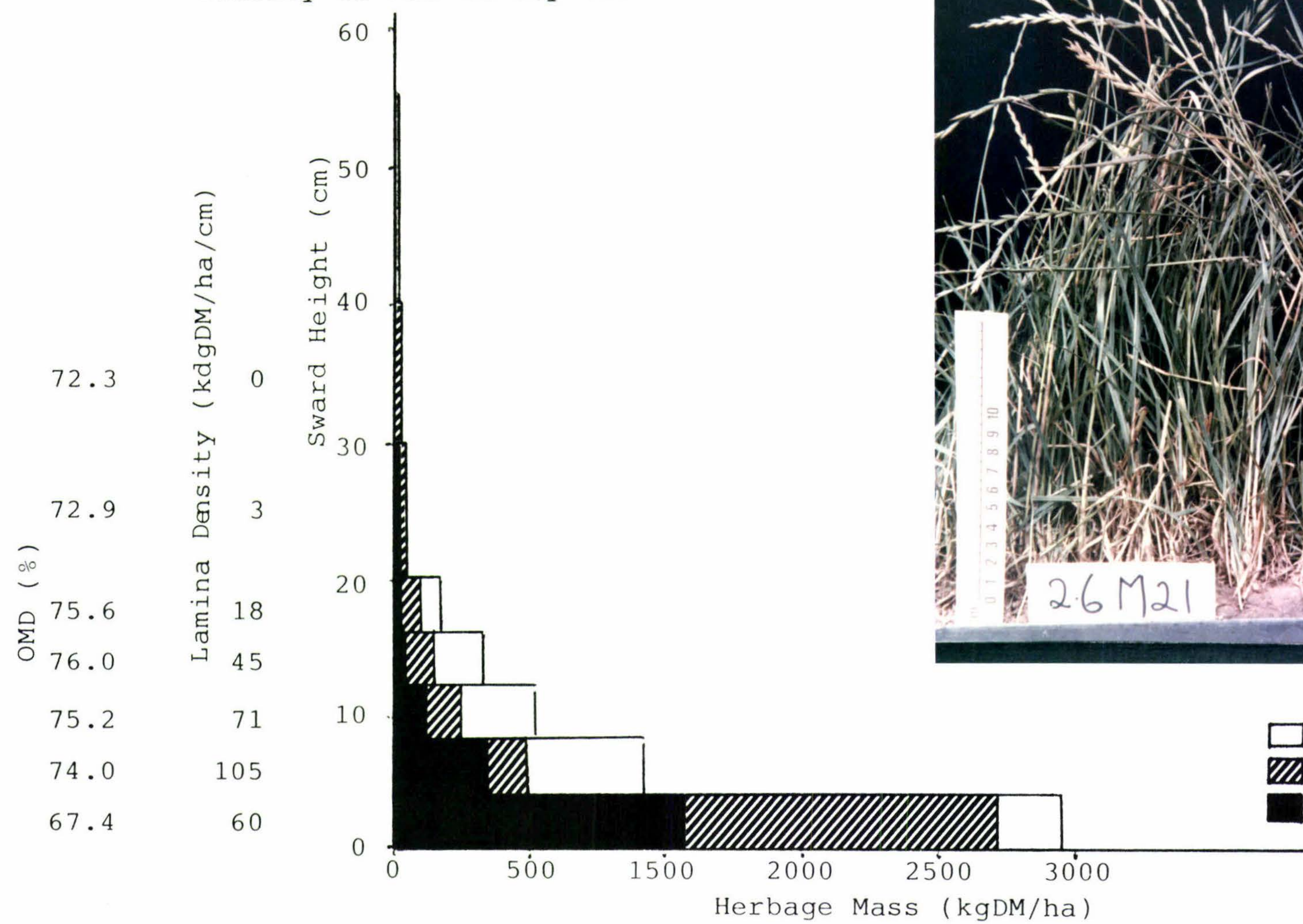
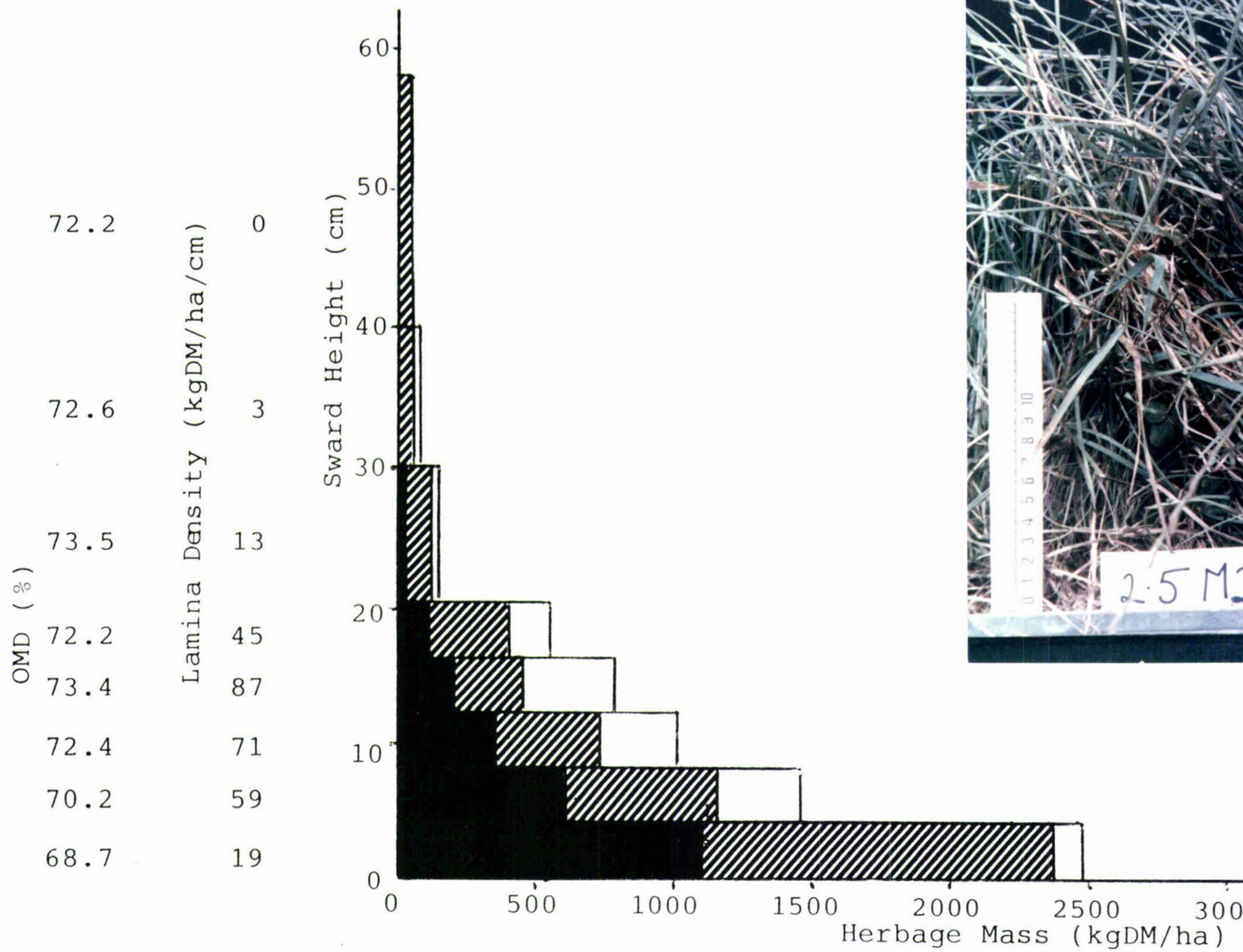


Figure 4.14g, Plate 4.1g Canopy Structure and Horizon OMD and Lamina Bulk Density of M28 on day 83.



lamina. Organic matter digestibility and lamina density of the top horizons in M21, M28 and L14 were also lower than on H14, M7 and M14.

4.3.2 Sward Height

Changes in pre- and post-grazing sward height are shown in Figures 4.15a and 4.15b respectively. Substantial differences between treatments in both pre- and post-grazing height quickly developed during the treatment period. Within the intensity comparison both the pre- and post-grazing sward height of L14 was substantially and increasingly greater than H14 and M14, the latter being intermediate of the other two. Within the frequency comparison sward height increased as the length of spell increased, but M21 and M28 were notably taller than M7 and M14 especially in post-grazing height.

Over the post-treatment period differences in both pre- and post-grazing sward height were reduced until, by day 168, differences were small and inconsistent.

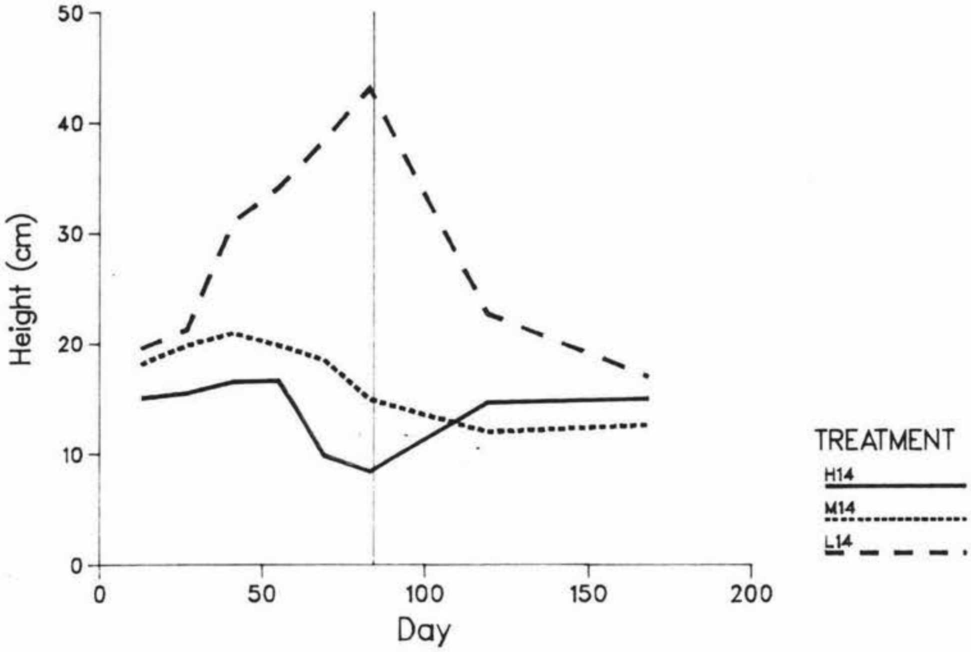
4.3.3 Herbage Bulk Density

By day 83 the total pregrazing bulk density of M7 was much

Figure 4.15a Pregrazing Sward Height (cm).

i) Intensity

***	***	***	**	*	Significance
1.6	1.7	2.0	2.2	1.1	SED



ii) Frequency

***	***	***	**	*	Significance
1.6	1.7	2.0	2.2	1.1	SED

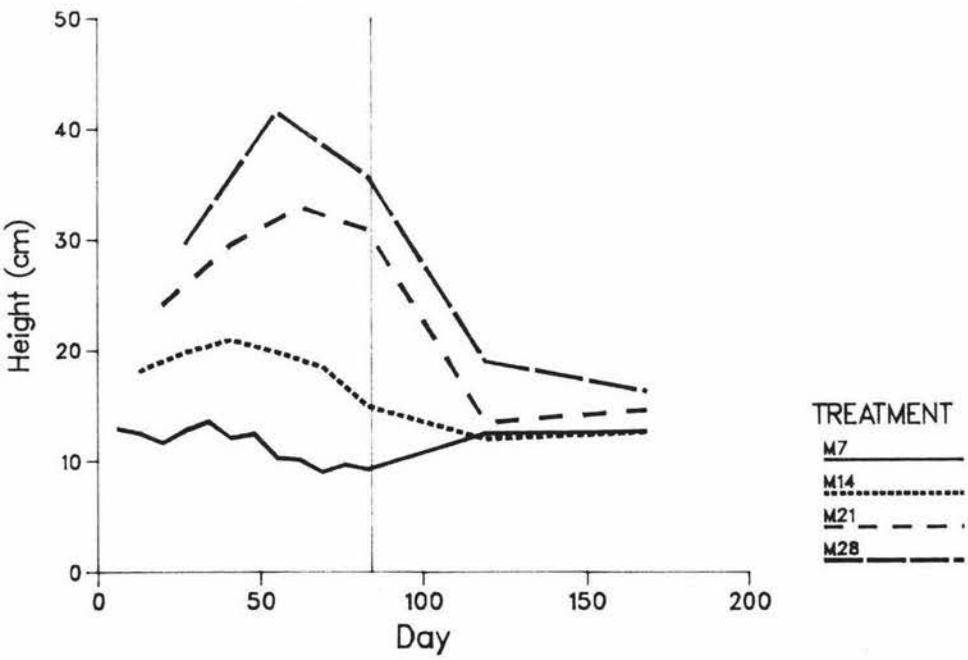
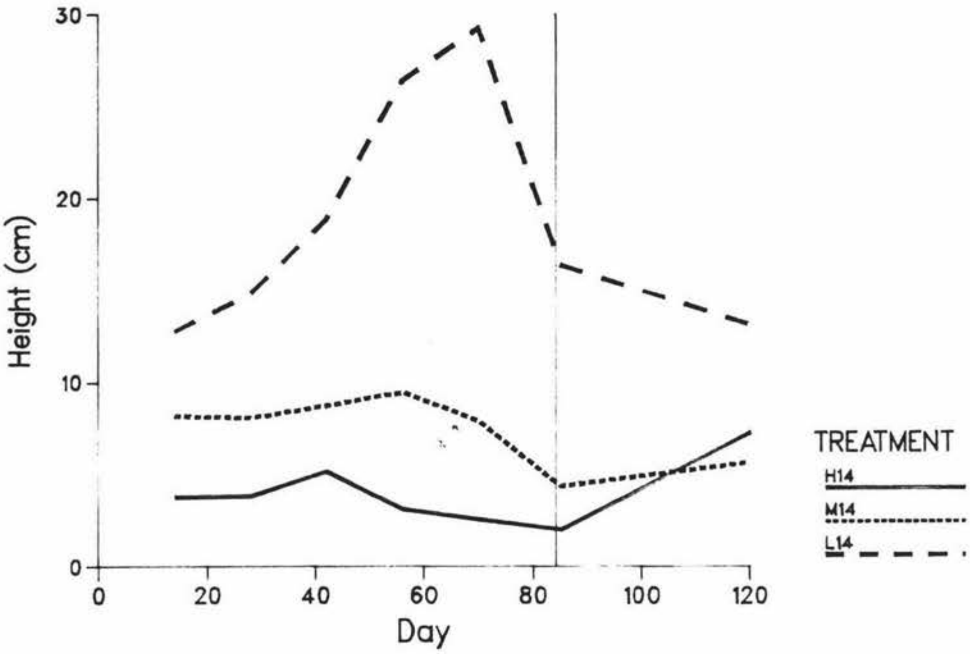


Figure 4.15b Post-Grazing Sward Height (cm).

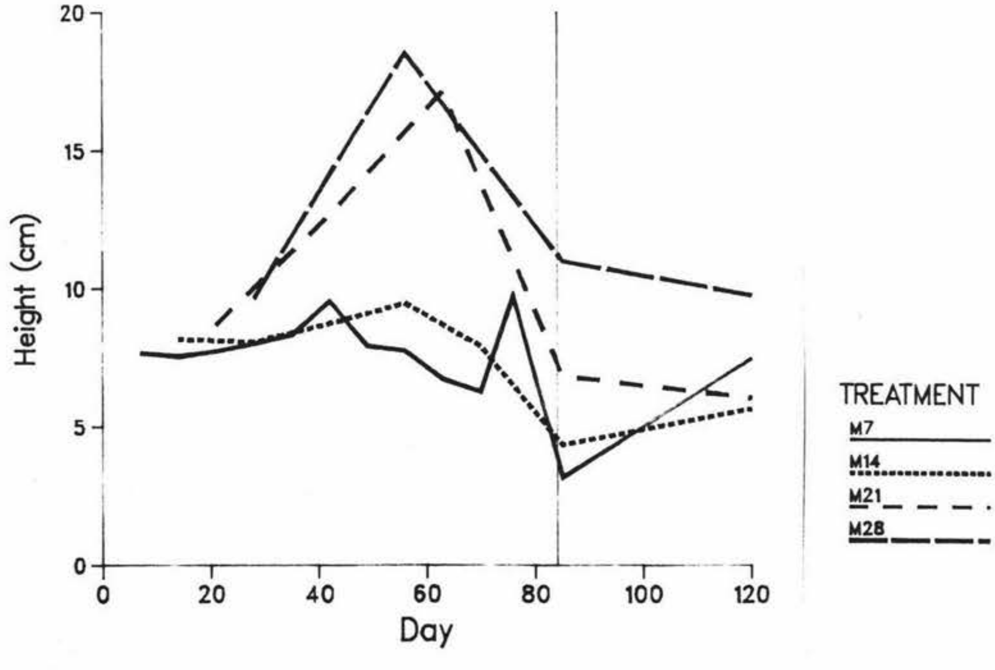
i) Intensity

***	***	***	***	Significance
0.5	1.4	1.9	1.1	SED



ii) Frequency

***	***	***	***	Significance
0.5	1.4	1.9	1.1	SED



greater than any other treatment (Table 4.7a) and that of H14 and M14 greater than that of M21, M28 and L14. These differences quickly disappeared over the post-treatment period.

By day 83 pregrazing lamina bulk density was greater with more intense and more frequent grazing. By day 168 differences within the frequency comparison had become small. But lamina density of H14 and especially M14 were much greater than L14.

4.3.4 Light Interception

Within the intensity comparison pregrazing light interception was greater with less intense grazing (Figure 4.16a) although that of M14 was not significantly different to that of L14 on days 27 and 83 and to that of H14 on day 55.

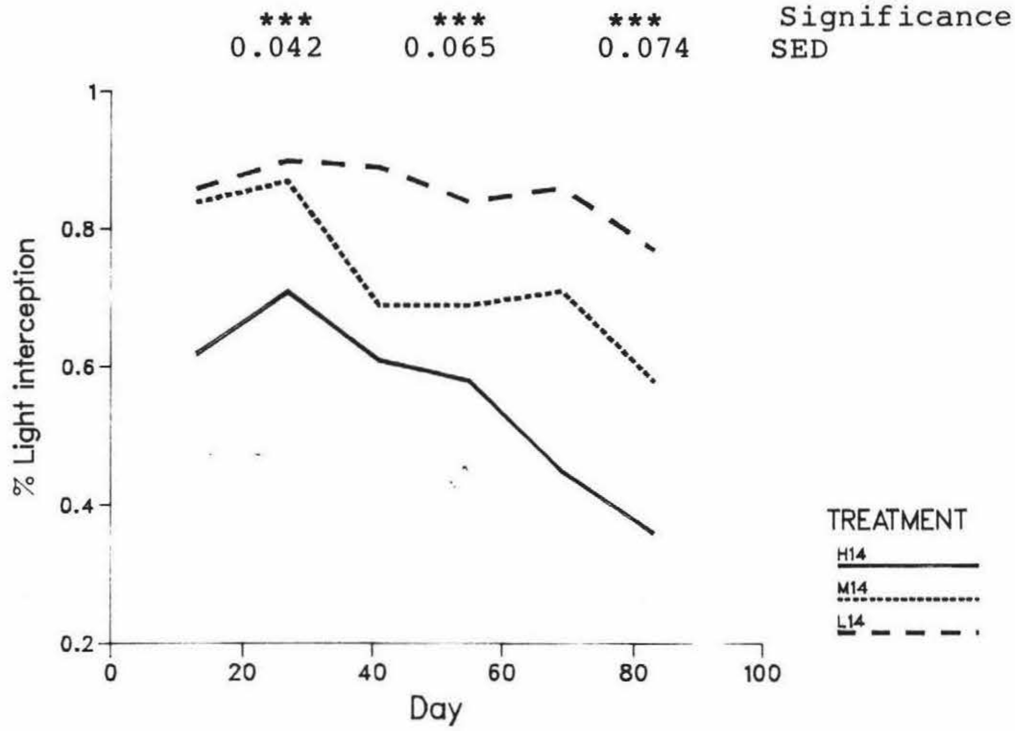
Pregrazing light interception also increased with less frequent grazing (Figure 4.16b). On M7 plots it was always significantly less than M21 and M28. On M14 it was generally intermediate of M7 and M21, but on days 55 and 83 light interception on M14 was not significantly lower than on M21.

Table 4.7 Bulk Density of a) Total and b) Lamina Pregrazing Herbage Mass on days 83 and 168 (kgDM/ha/cm).

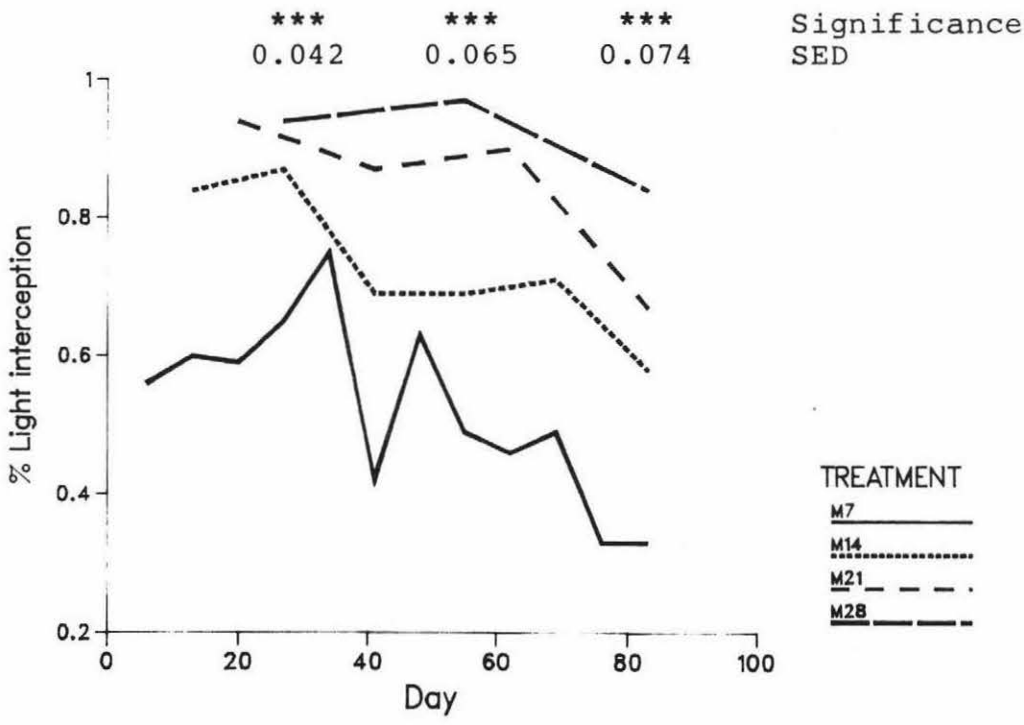
	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Total							
83	278 b	261 ab	147 a	410 c	261 ab	160 a	198 ab
168	247 a	312 a	300 a	319 a	312 a	288 a	335 a
b) Lamina							
83	102 c	84 bc	29 a	124 c	84 bc	43 ab	48 ab
119	111 b	138 c	66 a	138 c	138 c	122 b	107 b

Figure 4.16 Pregrazing Light Interception (%) during the Treatment Period.

a) Intensity



b) Frequency



4.3.5 Leaf Area Index

Within the intensity comparison there were no significant differences in pregrazing LAI (Figure 4.17). Post grazing LAI initially increased with reduced grazing intensity but by day 83 differences were very small (Appendix Table 3h).

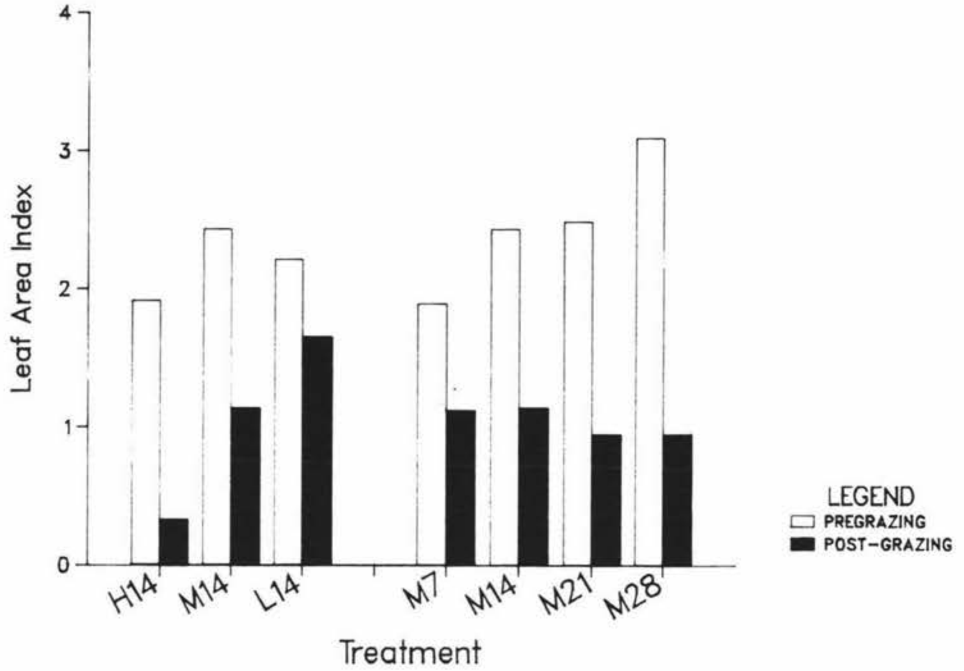
Within the frequency comparison pregrazing LAI increased with less frequent grazing (Figure 4.17) but these differences became smaller as the treatment period progressed (Appendix Table 3h). There were no differences in post grazing LAI (Appendix Table 3h).

There were no differences in LAI on days 85, 119 and 120 (Appendix Table 3h).

4.4 ORGANIC MATTER DIGESTIBILITY

On day 83 there were no significant differences in Organic Matter Digestibility (OMD)(Table 4.8). However, analysis on bulked herbage dissection samples on day 83 indicated that the OMD of reproductive stubble on treatments L14, M21 and M28 were about 5% lower than on treatments H14, M7 and M14. Vegetative ryegrass stubble on the other hand was higher in the former and there was little difference in lamina (OMD about 76%) or dead herbage (OMD about 57%) between treatments.

Figure 4.17 Mean* Pre- and Post-Grazing Leaf Area Index over the Treatment Period**.



* Means of days 27, 55 and 83 for Pre Grazing and days 28 and 56 for Post Grazing.

** See Appendix Table 3h for a complete table of LAI and statistical analysis.

Table 4.8 Organic Matter Digestibility of Total Pregrazing Herbage and Herbage Components on day 83.

	H14	M7	M14	L14	M21	M28
Total Pregrazing Herbage	72.8a	70.2a	72.2a	69.5a	71.0a	70.3a
Vegetative Ryegrass*						
Lamina		77.0	(1)**		75.5	(1)
Stubble		72.5	(1)		77.8	(1)
Reproductive Ryegrass*						
Lamina		76.0	(1)		-	
Stubble		73.4	(1)		68.6	(3)
Dead Herbage*						
Leaf		56.2	(3)		58.0	(3)
Stem		57.3	(3)		58.5	(3)

* Samples bulked according to the two groups

** Number of samples in mean value

4.5 HERBAGE ACCUMULATION

The herbage accumulation data is broken down into 8 periods:

Period	1	days	0- 27
	2		28- 55
	3		56- 83
	4		85-119
	5		120-168
	6		0- 83
	7		85-168
	8		0-168

All data presented here, where required, have been adjusted for accumulation during the grazing period.

Data for M21 during the periods 1, 2 and 3 could not be included as the grazings for this treatment could not be adjusted to a full 28 day interval. During these periods, therefore, only 5 treatments were included in the analysis of variance.

Full tables of Total, Green, Total Lamina, White Clover Lamina and Total, Other Grasses Lamina and Total, Total, Vegetative and Reproductive Stubble and Dead Herbage accumulation, and the proportion of species in lamina accumulation (with relevent statistics) are given in Appendix Tables 4a-h respectively.

4.5.1 Total

Total herbage accumulation over the trial (24 weeks) ranged from 10130 to 13490 kgDM/ha (Figure 4.18). Approximately 70% of this total herbage accumulated during the treatment period. Total herbage accumulation rates were 82, 104, 105, 64 and 33 kgDM/ha/day for periods 1-5 respectively, averaged over the appropriate number of treatments. There were no significant differences in total herbage accumulation over the whole trial or during the treatment period. However during the post-treatment period total herbage accumulation was significantly lower on L14.

4.5.2 Green

Over the complete trial period more green herbage

Figure 4.18 Total, Green and Dead Herbage Accumulation (kgDM/ha).

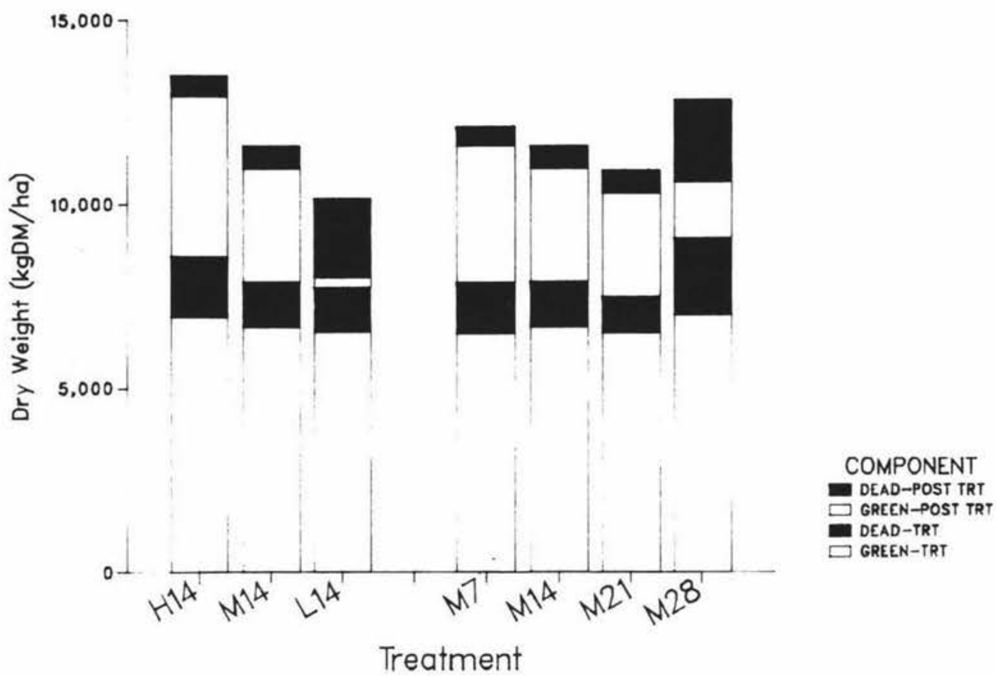
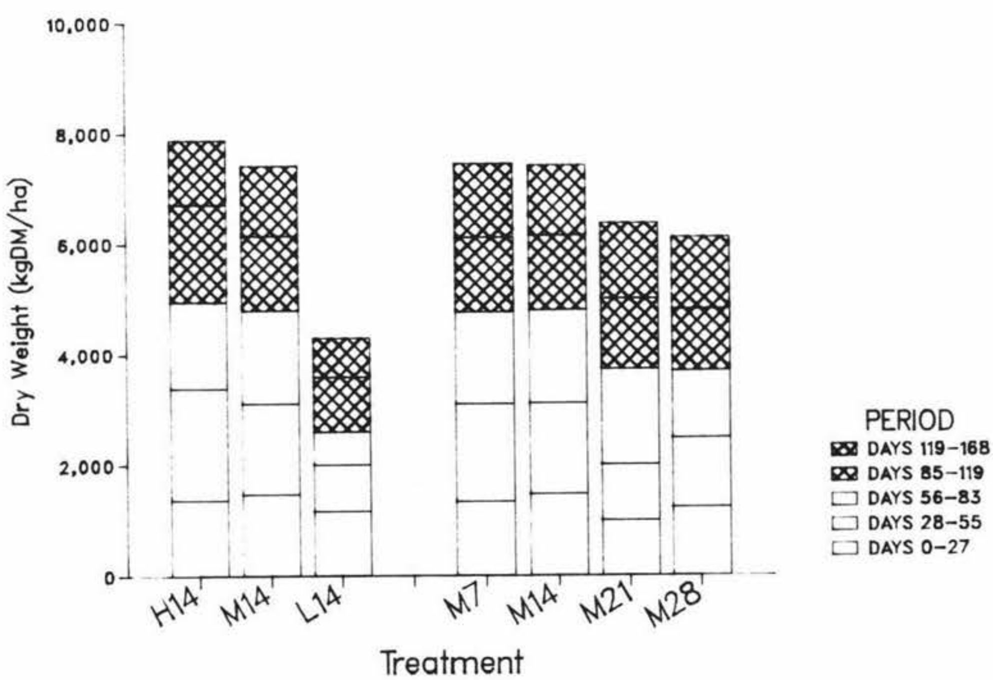


Figure 4.19 Total Lamina Accumulation over the Treatment and Post-treatment Periods (kgDM/ha).



accumulated on H14 (66%) and M14 (37%) than L14; and with M7 (20%) and M14 or M21 (10%) than M28 (Figure 4.18). These differences were due solely to very large, significant differences in green herbage accumulation over the post-treatment period, especially between days 85 and 119 (Appendix Table 4b).

Over the treatment period green herbage accumulation accounted for about 80% of total herbage accumulation and amounted to 63, 92 and 82 kgDM/ha/day for periods 1 to 3 respectively.

4.5.3 Lamina

There were large significant differences in lamina accumulation especially during the treatment period (Figure 4.19).

In the intensity comparison lamina accumulation of L14 was approximately 47% below that of H14 and M14. In the frequency comparison M7 and M14 had similar levels of lamina accumulation whereas M21 and M28 were about 22% lower (ns).

During the post-treatment period L14 had significantly less lamina accumulation than that of H14 (42%) and M14 (35%). There were no significant differences within the frequency comparison. However, during days 85-119, H14 had greater lamina accumulation than M14 (29%) and L14 (76%), and M7 and M14 had greater lamina accumulation than M28 (29%) and M21 (7%), although neither of these differences were significant (Appendix Table 4c).

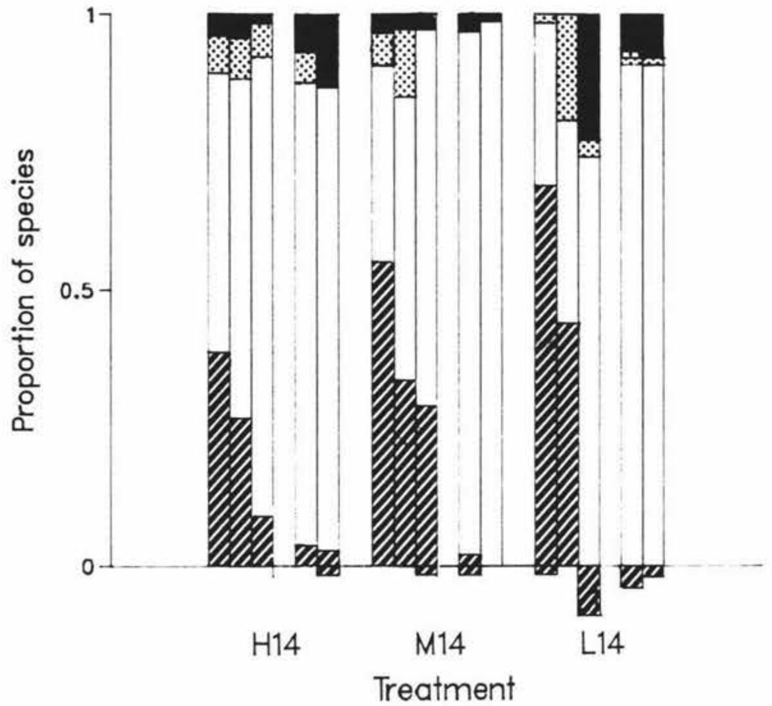
Over the whole trial the lamina accumulation of L14 was 40% lower than that of H14 and M14; and that of M21 and M28 were 14% and 18% below that of M7 and M14.

Maximum lamina accumulation rates for periods 1-5 were 53, 72, 59, 52 and 29 kgDM/ha/day respectively. For the first 3 periods these accounted for a maximum of 84%, 78% and 72% of average green herbage accumulation respectively.

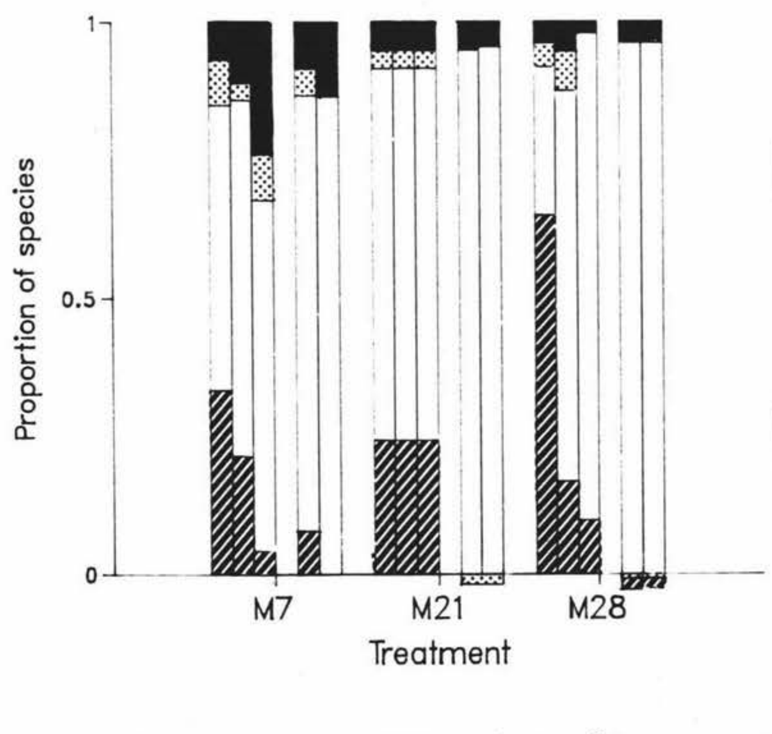
Ryegrass was always the major component of lamina accumulation (Figure 4.20). However in periods 2 and 3 the proportion of white clover in M7 lamina accumulation was greater than other treatments. During the post-treatment period both H14 and M7 had a greater proportion of white clover lamina accumulation though this was only significant during period 5. The greater proportions of white clover in L14 during periods 2 and 3 were due to lower total lamina accumulation (Figure 4.19) rather than increased accumulation of white clover lamina (Appendix Table 4d).

Figure 4.20 Proportion of Ryegrass, White Clover and Other Grass Lamina Accumulation in Total Lamina accumulation*.

a) Treatments H14, M14 and L14



b) Treatments M7, M21 and M28



* for key see Fig. 4.2 p83a

There were no differences in the proportion of other grasses in lamina accumulation (Figure 4.20, Appendix Table 4h).

4.5.3.1 Ryegrass

During the treatment period differences in ryegrass lamina accumulation were due to differences in the accumulation of lamina on both vegetative and reproductive tillers whereas during the post-treatment period lower lamina accumulation of L14 was solely due to that on vegetative tillers (Table 4.9).

The proportion of reproductive lamina accumulation in total ryegrass lamina accumulation declined from 40-70% (Period 1) to -12-27% (Period 3) during the treatment period. During Period 1 there were no differences in total ryegrass lamina accumulation because lower vegetative accumulation on L14 and M28 were associated with greater reproductive lamina accumulation. However during Period 2 total ryegrass lamina accumulation declined with reduced grazing intensity and frequency. This was solely due to vegetative lamina accumulation which was especially reduced on L14 compared with the other treatments. During Period 3 vegetative lamina accumulation declined with reduced grazing severity but in M14 this was associated with greater reproductive

Table 4.9 Ryegrass a) Vegetative b) Reproductive and c) Total Lamina Accumulation (kgDM/ha).

	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
a) Vegetative							
1	720 a	540 a	380 a	690 a	540 a		350 a
2	1310 c	810 b	340 a	1130 bc	810 b	(2090)	850 b
3	1320 b	1060 b	560 a	1050 b	1060 b		1070 b
4	1500 a	1330 a	970 a	1080 a	1330 a	1200 a	1110 a
5	1020 b	1250 b	640 a	1160 b	1250 b	1310 b	1280 b
b) Reproductive							
1	530 ab	790 bc	800 c	460 a	790 bc		800 c
2	490 a	470 a	350 a	350 a	470 a	(1280)	230 a
3	120 a	390 b	-80 a	90 a	390 b		130 a
4	60 bc	30abc	-50 a	110 c	30abc	-10 ab	-20 ab
5	20 a	-10 a	-10 a	0 a	-10 a	10 a	-10 a
c) Total							
1	1250 a	1330 a	1180 a	1150 a	1330 a		1150 a
2	1800 d	1280 bc	690 a	1510 cd	1280 bc	(3370)	1070 ab
3	1440 a	1450 a	480 b	1140 a	1450 a		1200 a
4	1570 a	1360 a	920 a	1200 a	1360 a	1190 a	1100 a
5	1040 b	1240 b	630 a	1160 b	1240 b	1320 b	1270 b

accumulation. Within the frequency comparison both M7 and M28 had lower ryegrass lamina accumulation than M14.

4.5.3.2 White Clover and Other Grasses

White clover lamina accumulation was greater on treatment M7 than other treatments throughout the trial (Figure 4.20, Appendix Table 4d). Increased white clover lamina accumulation was also found on H14 swards during period 5 (days 120-168).

At no stage were there significant differences in the lamina accumulation of other grasses (Appendix Table 4e).

4.5.4 Stubble

Over the total period of the trial there were no differences in total stubble accumulation (Appendix Table 4f). However, stubble accumulation on L14, M21 and M28 plots were 88%, 48% and 76% (respectively) greater than the average of H14, M7 and M14 during the treatment period, but much lower (and negative) during the post-treatment period (especially days 85-119). Most of the stubble accumulation during the treatment period was after day 28 but differences during the treatment period were not significant.

There were, with one minor exception, no significant differences in 'vegetative' stubble accumulation during the entire trial (Appendix Table 4f). Therefore differences in stubble accumulation are directly attributable to ryegrass reproductive stubble.

There were no significant differences in reproductive stubble accumulation during the treatment period (Figure 4.21). However that of L14 was 2.5 times that of H14 and 50% greater than M14 during this time. Reproductive stubble accumulation on M21 and M28 was also 34% greater than on M14 and on M7 it was negligible.

During the post-treatment period reproductive stubble died (especially between days 85 and 119- Appendix Table 4f) and losses were much greater on L14 and M28 (and to a lesser extent on M21) than on H14, M7 and M14.

4.5.5 Dead

At no time were there significant differences in dead

Figure 4.21 Ryegrass Reproductive Stubble Accumulation over the Treatment and Post-treatment Periods (kgDM/ha).

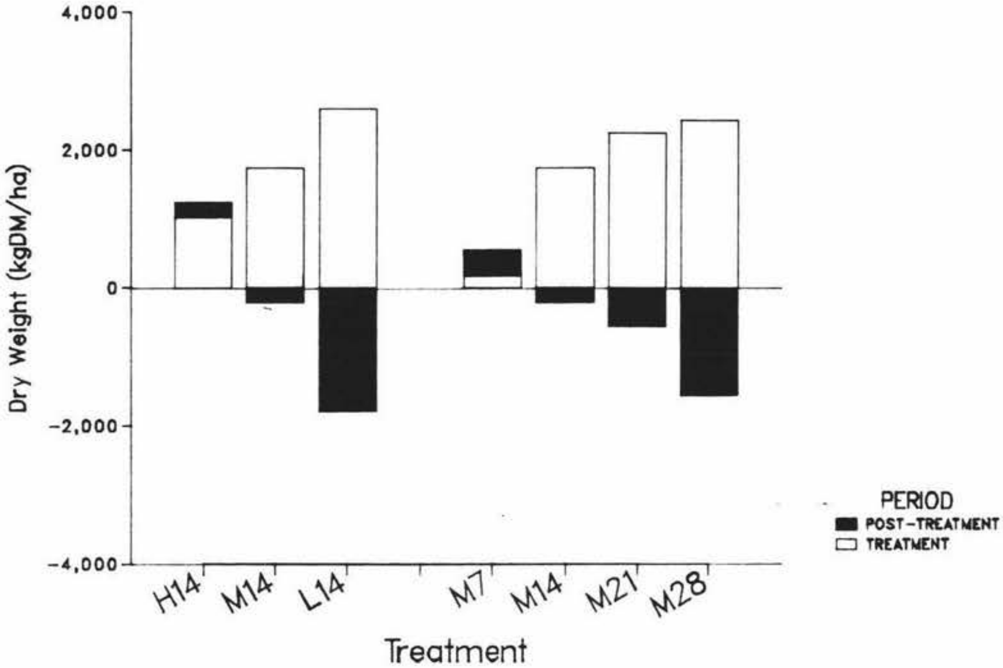
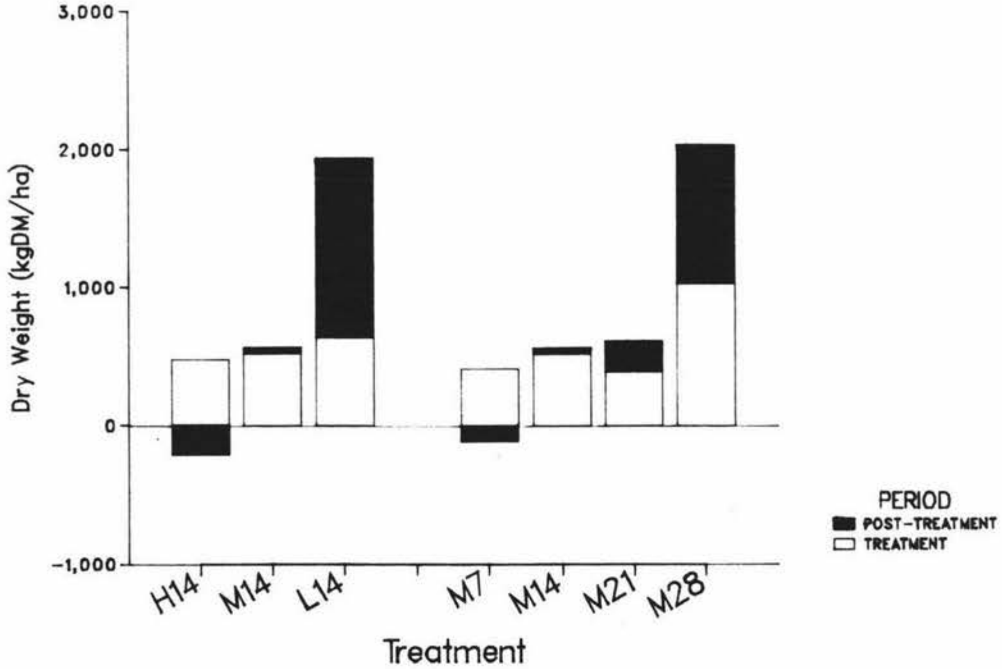


Figure 4.22 Dead 'Stem' Accumulation over the Treatment and Post-treatment Periods (kgDM/ha).



'leaf' accumulation (Appendix Table 4g) nor were there significant differences in dead 'stubble' accumulation during the treatment period although that of M28 was more that twice that of M7, M14 and M21 (Figure 4.22) (N.B. see section 4.1.5 for definitions of 'leaf' and 'stubble').

During the post-treatment period, however, substantially more dead 'stubble' accumulated in M28 and L14 swards as a result of the greater quantities of reproductive stubble dying (see section 4.4.4). These differences largely arose during days 85-119 (Appendix Table 4g).

CHAPTER 5 DISCUSSION

5.1 INTRODUCTION

The objective of this study was to examine a range of spring grazing frequency and intensity and to identify:

1. whether or not 'control' (or some intermediate state) resulted;

2. why differences between managements arose; and

3. examine the effect of those managements on subsequent pasture production during summer and early autumn.

Pastures will be catagorized (section 5.2) on the basis of the level of pasture 'control' resulting from the grazing managements imposed (Objective 1). Pasture 'control' was defined in Chapter 1 in terms of herbage mass, sward structure, herbage accumulation and botanical composition, with emphasis on the leaf (lamina) and stubble components. The first three characteristics will be examined in sections 5.3-5.5 respectively to determine why differences between treatments arose during the treatment period (Objective 2). Subsequent pasture performance arising from the spring treatments is discussed in section 5.6 (Objective 3) and section 5.7 will examine the effect of those treatments on sward digestibility at the end of the treatment period and changes in the dead herbage content of the pastures over the post-treatment period. Ryegrass was the most important component of herbage throughout the trial (Table 5.1, Figure 4.2) and discussion on the effect of grazing management on other species (mainly white clover and Poa spp) during the treatment and post-treatment periods is mostly reserved for section 5.8.

Obviously, pasture 'control' must relate to the end user of the herbage and therefore in this thesis the likely effects on animal performance of the spring managements will be discussed (section 5.9). Spring grazing criteria will be established as a practical aid to maintaining 'control' of pastures and recommendations for spring grazing management will be made (section 5.10). Finally, the need for further research in these areas will be discussed (section 5.11).

5.2 TREATMENTS AND PASTURE CONTROL

The first objective of this thesis was to identify whether or not pasture 'control' resulted in each of the treatments imposed. As hard and lax grazing was expected to result in swards which would be considered 'controlled'

Table 5.1 **Stepwise Regression of Herbage Mass Components.**

Dependent Variable	Independent Variable	Increment of R^2 day 27	day 55	day 83	day 119	day 168
Total	Green	91*	90	95	0ns	0 ns
	Dead	9	10	5	82	83
Dead	'Leaf'	100	85	88	7	12
	'Stubble'	0ns	15	12	93	88
Green	Lamina	0ns	0ns	6	0ns	91
	Stubble	91	90	94	71	9
Green	Ryegrass	96	90	92	77	83
	Other Grasses	2	8	1	4	2
	White Clover	2	2	7	19	15
Lamina	Ryegrass	97	92	92	91	97
	Other Grasses	1	3	2	3	0 ns
	White Clover	2	5	6	7	3
Stubble	Ryegrass	96	93	92	72	83
	Other Grasses	1	6	1	4	5
	White Clover	3	1	7	23	11
Ryegrass	Vegetative	12	16	11	56	88
	Reproductive	88	84	89	44	12
Ryegrass	Lamina	9	11	5	67	88
	Stubble	91	89	95	33	12
Ryegrass Lamina	Vegetative	26	75	91	97	99
	Reproductive	73	25	9	3	1

* $P < 0.001$ except where stated

<u>Table 5.1 (continued)</u>

Dependent Variable	Independent Variable	Increment of R^2 day 27	day 55	day 83	day 119	day 168
Ryegrass Stubble	Vegetative	4	2	2	42	86
	Reproductive	96	98	98	58	14
Ryegrass Reproductive Stubble	Undefoliated Reproductive Tiller Density	24	18	32	80	-
	Individual Tiller Mass	74	80	62	6	-

and 'uncontrolled' respectively, the other treatments may be grouped according to whether the analysis of important characters places them with either of these treatments or intermediate of them.

Examination of the most important results (summarised in Table 5.2) shows that swards resulting from the spring treatments can be separated into two distinct groups. As a result no multivariate analysis was required to enable a grouping of treatments to be made. Reasons for including results for examination in Table 5.2 will be made clear in sections 5.3-5.7. Swards resulting from treatments H14, M7 and M14 may be considered as 'controlled' whereas those resulting from treatments L14, M21 and M28 may be considered as 'uncontrolled'.

Swards M21 and M28 could possibly be considered intermediate of L14 and the 'controlled' swards in post-treatment lamina accumulation. However the results obtained must be dependent on the grazing intensity and frequency chosen over that period (Brougham 1959b) and given a different set of management decisions and climate, results may have been quite different (see section 5.6). It may therefore be better to regard swards in the light of the potential risk of reduced lamina accumulation rather than the actual results achieved. In that case it is probable that higher risk was associated with treatments M21 and M28 as well as L14 given the

Table 5.2 Summary of Major Results at Day 83*.

Sward Characteristics	Analysis of Variance
Pregrazing Herbage Mass	
Total	H14 M7,M14 < M21 M28,L14
Green	H14 M7,M14 < M21,M28,L14
Ryegrass Reproductive	H14,M7,M14 < M21,M28,L14
Total Dead	H14,M7< M14,M21 < M28,L14
Percent Reproductive in Total Ryegrass	H14,M7,M14 < M21,M28,L14
L:S Ratio	H14,M7,M14 < M21,M28,L14
Ryegrass Reproductive Tiller Density	H14,M7 < M14,M21,M28,L14
Individual Tiller Mass	H14,M7,M14 < M21 M28,L14
Emerged Inflorescence Density	H14< M7,M14 < M21< M28< L14
Ryegrass Vegetative Tiller Density	M7 H14,M14 > M21,M28,L14
Individual Tiller Mass	H14,M7,M14 < M21,M28,L14
Sward Height	H14 M7,M14 < M21,M28< L14
Light Interception	H14,M7< M14 ⩽ M21,L14< M28
Lamina Accumulation	
Treatment Period	H14,M7,M14 > M21,M28> L14
Post-treatment Period	H14,M7,M14,M21,M28 > L14

* except lamina accumulation: measured over the treatment and post-treatment periods.

similarities of the swards resulting from these three treatments.

Therefore within the range of treatments imposed on the swards it appears that this grouping may be considered as absolute. That is, there is no gradation of sward condition between the 'controlled' and 'uncontrolled' status so far as key sward characteristics are concerned. This does not mean, of course, that there will not be circumstances where an intermediate condition will occur, or that animal performance from equitable grazing of some of these swards will not be intermediate of others (see section 5.7).

In the following sections it will be apparent that differences in sward characteristics (Table 5.2) are largely a direct result of changes in the ryegrass reproductive component of the sward or the influence of this component on other sward characteristics.

5.3 EFFECT OF GRAZING MANAGEMENT ON HERBAGE MASS

5.3.1 Ryegrass Reproductive Stubble Mass

During the treatment period differences in total and green herbage mass were mainly influenced by ryegrass reproductive stubble mass in both the treatment (mainly as green herbage) and post-treatment (as dead herbage) periods (Figure 4.1, Table 5.1). The separation of treatments into two groups with respect to total, green and ryegrass reproductive stubble masses is apparent. Treatments M7, M14 and H14 fall into one group (relatively low herbage mass) and treatments M21, M28 and L14 into the other (relatively high herbage mass). Differences in herbage mass largely arose between days 27 (October 22) and 55 (November 18) coinciding with rapid stem elongation (Figure 4.15a,b) and inflorescence emergence (Figure 4.12). Similar results have been found by others. For example, Korte (1981), Holmes and Hoogendorn (1983) and Hoogendorn et al (1985) found that lax grazed pastures had a much (2-3 times) greater content of stubble than hard grazed swards. Wilman et al (1976a,d) found that the mass of stem and ear increased substantially as the spell between defoliation was increased from 3 to 10 weeks. Tainton (1974a,b) and Korte (1981) both found that delaying defoliation past 95% light interception increased the mass of culm in the sward compared to grazing at 95% light interception. In this trial light interception before grazing in treatments M21, M28 and L14 were also much greater than that of H14, M7 and M14 (Figure 4.16).

5.3.2 Determinants of Ryegrass Reproductive Stubble Mass

The level of reproductive herbage mass in a sward is a resultant of two components: individual reproductive tiller mass and reproductive tiller density. Reduction in either one of these components may be important in inhibiting the build up of reproductive herbage mass. For example, Korte et al (1984) found that pasture 'control' was 'obtained by hard grazings which killed reproductive tillers'. The importance of reduction in reproductive tiller density for pasture 'control' has also been highlighted by Hughes (1983) and Smetham (1983).

The results of this trial however, show that differences in individual reproductive tiller mass (Figure 4.13) may be more important in determining differences in reproductive herbage mass between treatments. It would be expected that the reproductive tiller density of the M14 treatment at day 83 be similar to M7 and H14. It was, however, similar to that of L14, M21 and M28 treatments at day 83 (Figure 4.11). Individual reproductive tiller mass of M14, on the other hand, was very similar to that of H14 and M7 and was significantly lower than L14, M21 and M28 (Figure 4.13). It would appear then that differences in the quantity of reproductive stubble that had accumulated by day 83 was largely due to differences in the mass of the individual reproductive tillers rather than the density of those tillers. Regression analysis (Table 5.1) confirms this point. Throughout the treatment period individual reproductive tiller stubble mass made a greater contribution to ryegrass reproductive stubble than did reproductive tiller density. This points to the possibility of using reproductive tiller mass as the criteria for spring pasture management. This is further discussed in section 5.10.

Differences in individual reproductive tiller mass may be a result of individual tiller mass/density relationships within the swards or due to differences in the extent and timing of reproductive tiller removal by grazing sheep.

As expected (Kays and Harper 1974, Grant et al 1981b,1983, Bircham and Hodgson 1983a,b) vegetative tiller density was negatively correlated (at least on days 55 and 83), and individual vegetative tiller mass was positively correlated, with both total and green herbage mass (Table 5.3). That is, swards of H14, M7 and M14 had a high density of small tillers whereas those of M21, M28 and L14 had a lower density of larger tillers (Figures 4.8 and 4.9). Similarly, individual reproductive tiller mass was positively correlated with both total and green herbage mass and vegetative tiller mass and negatively correlated with vegetative tiller density (Table 5.4). Rhodes (1968) also found evidence for decreased size of reproductive tillers under increased competition. Maintenance of low herbage mass and therefore low light interception ensures that reproductive tillers remain small.

Table 5.3 Correlations between Pregrazing Herbage Components and a) Total and b) Green Herbage Masses on days 27,55,83,119 and 168.

Herbage Component	Day 27	Day 55	Day 83	Day 119	Day 168
	(correlation coefficients: r)				
a) Total					
Individual Ryegrass Reproductive Tiller Mass	0.82 ***	0.75 ***	0.78 ***	ns	ns
Reproductive Tiller Density	0.61 **	0.43 *	0.67 ***	ns	ns
Individual Ryegrass Vegetative Tiller Mass	0.68 ***	0.71 ***	0.76 ***	0.72 ***	ns (.07)
Vegetative Tiller Density	ns	-0.68 ***	-0.47 *	-0.63 ***	ns
b) Green					
Individual Ryegrass Reproductive Tiller Mass	0.84 ***	0.86 ***	0.81 ***	ns	ns
Reproductive Tiller Density	0.55 ***	ns (.08)	0.70 ***	0.41 *	ns
Individual Ryegrass Vegetative Tiller Mass	0.79 ***	0.75 ***	0.80 ***	ns	0.51 *
Vegetative Tiller Density	ns	-0.74 ***	-0.51 **	-0.62 **	-.078 ***

Table 5.4 Correlations between Individual Ryegrass Reproductive Tiller Mass and Other Sward Characteristics.

Character	Day 27	Day 55	Day 83
Sward Height	0.79* ***	0.76 ***	0.87 ***
Total Herbage Mass	0.82 ***	0.75 ***	0.78 ***
Green	0.84 ***	0.86 ***	0.81 ***
Individual Ryegrass Vegetative Tiller Mass	0.71 ***	0.68 ***	0.73 ***
Vegetative Ryegrass Tiller Density	-0.44 *	-0.72 ***	-0.57 **
Emerged Inflorescence Density	-	0.72 ***	0.79 ***

* correlation coefficient (r)

Reproductive tiller density is initially determined by the processes of vernalization and floral initiation (Wilson 1959, Jewiss 1972), and changes in reproductive tiller density will only occur through removal of the apical meristem and are not plastic as are changes in vegetative tiller density. If the inflorescence is not removed development will continue, herbage mass will increase and the light environment deteriorate.

In practice the inflorescence must be removed before, or soon after, emergence as sheep are unlikely to consume it at a later stage, even with hard grazing (Hughes 1983). The density of reproductive tillers with emerged inflorescence (Figure 4.12) was very much less in treatments H14, M7 and M14 than in M21, M28 and L14 despite a similar density of undefoliated reproductive tillers during most of the treatment period (Figure 4.11). However, many more reproductive tillers appeared in treatments H14, M7 and M14 than in treatments M21, M28 and L14 (Table 4.6) and would have been removed by the grazing sheep before they were able to develop. Those reproductive tillers that did reach maturity, especially in H14 and M7 (see Figure 4.12), would probably have been mostly secondary reproductive tillers that form after the primary tillers have been removed (Hill and Watkin 1975, Korte et al 1984) whereas in the swards of M21, M28 and L14 most of the emerged inflorescence would have been primary reproductive tillers.

Korte (pers. comm.) and Langer (1957) also found that up to 50% more secondary reproductive tillers may develop under more intensive management after removal of existing primary reproductive tillers. The number of reproductive tillers that appeared in this study (Table 4.6) are somewhat higher than reported by Korte (1981), Browse et al 1984 and Hebblethwaite (1977) of between 3000 and 3900 reproductive tillers per sq. m. Korte (1981) found that about 2200-2400 tillers per sq. m emerged in an initial group (October) with a further 1000 tillers per sq. m developing in November and December. The timing of reproductive development was similar to that previously reported at Palmerston North for 'Grasslands Ruanui' perennial ryegrass in pots (Wilson 1959), seed production trials (Hill and Watkin 1975) and under grazing (Korte 1981). The 'Grasslands Nui' pastures used in this trial would not be expected to behave differently (Armstrong 1977).

Inflorescence emergence (Figure 4.12) began in late October (between days 27 and 35). Floral initiation must therefore have occured in late August and September (Wilson 1959, Langer 1980). These results are similar to those of Korte et al (1984) who found that 28% of the final number had emerged by early November and 50% by 23 November. As reported by Korte (1981) and Wilson (1959) for 'Grasslands Ruanui' ryegrass, very few reproductive tillers emerged after mid-December.

The differences between swards in reproductive tiller appearance and consumption also explain the apparently later reproductive development in intensively grazed swards found in this study (Figure 4.12) and by Brougham (1961) and Chapman et al (1983).

5.3.3 Lamina Mass

Differences in both pre and post grazing lamina mass between treatments (Figure 4.1, Table 4.1a and 4.2a) were, for the most part, consistent with the use of lamina mass and length of spell as the management criteria. It is significant however, that differences within the intensity comparison were not always large because of lower lamina accumulation in lax grazed swards (see section 5.4). The greatest lamina mass during the treatment period was obtained on M28 plots which averaged 1600-1800 kgDM/ha before grazing, although individual plots ranged up to 2200 kgDM/ha. The maximum mean lamina mass in this trial was very similar to that obtained by Tainton (1974) of 1600 kgDM/ha, Wilman et al (1976a) of 1640 kgDM/ha and Jackson (1974) of between 1500 and 2500 kgDM/ha. Browse et al (1984) found that maximum lamina mass was about 2500, 1500 and 1000 kgDM/ha when swards were closed on for conservation on about Sept 29, Oct 20 and Nov 10 respectively. This peak occured between 20 and 40 days after closure and, at the two earlier dates, subsequently declined to about 500 kgDM/ha about 4 weeks later. Wilman et al (1976a) also found that although lamina mass peaked during reproductive growth at about week 5 after closure of the sward, lamina mass had declined to about 1480 kgDM/ha by week 8, 1060 kgDM/ha by week 10 and only 370 kgDM/ha by week 14.

5.4 EFFECT OF GRAZING MANAGEMENT ON SWARD STRUCTURE

The 'leafiness' (or its reciprocal, 'steminess') of a pasture is an important characteristic in defining the state of pasture 'control' as is the position and density of lamina in the canopy (i.e. canopy structure) (see Chapter 1). In all these characters the separation of treatments H14, M7 and M21 and treatments L14, M21 and M28 was clearly seen.

5.4.1 Leaf:Stem Ratio

The 'leafiness' of a sward can be expressed as a proportion of either green, total or species yeild, or as a ratio to dead leaf (Sheath and Bryant 1984) or stem (Bircham 1982, Wilman et al 1976a). In this study leaf:stem ratio was used.

Whereas the separation of treatments L14 and treatments M14 and H14 in pregrazing L:S ratio during the treatment period was distinct, the separation of swards within the frequency comparison was less clear because of the greater levels of lamina on less frequently grazed swards (Figure 4.3). However when L:S ratio was measured after grazing (i.e. when differences between lamina mass were small), then the separation of treatments M7 and M14 and treatments M21 and M28 was more evident.

Holmes and Hoogendorn (1983) also found similar differences between hard and lax grazed swards. Differences in L:S ratio between swards due to grazing frequency were observed by Wilman et al (1976a) and Bartholomew and Chestnutt (1978) who found that the L:S ratio declined from over 1.0 at about 3 weeks after defoliation to 0.34-0.51 after 6 weeks, and to 0.08-0.19 at 10 weeks. The first drop was largely due to an increase in the proportion of stem in the sward as between weeks 3 and 6 weeks lamina mass continued to rise. The drop between weeks 6-10 was due to both increasing mass of stem and declining mass of lamina within the swards.

In this trial differences in L:S ratio were almost solely due to changes in the L:S ratio of ryegrass reproductive tillers (Figure 4.4) as, with one exception, there were no differences in the L:S ratio of vegetative tillers . Differences in the L:S ratio of reproductive tillers was due to both increased mass of stubble (Table 4.1b) and decreased mass of lamina (Table 4.3). In treatment M7 however, L:S ratio at day 83 was lower than expected solely on the basis of reproductive stubble mass because of the higher proportion of non-reproductive stubble (Table 4.1c). This arose because of the greater proportion of white clover and other grasses in the sward (see section 5.8).

During the post-treatment period differences in L:S ratio disappeared (Figure 4.3) as the ryegrass reproductive stubble died (Figure 4.1). The use of leaf:non-leaf ratio (or the proportion of lamina to total rather than green herbage mass) may be a better description of lamina availability in the swards (Figure 4.5). Large differences in leaf:non-leaf were due to differences in the proportion of dead herbage in total herbage mass (Figure 4.7).

5.4.2 Canopy Structure and Sward Height

Greater reproductive development on L14, M21 and M28 swards also resulted in a greater intermingling of lamina and stubble within the sward canopy than on treatments M7, H14 and M14 (Figure 4.14).

Jackson (1974, 1975), Barthram (1981), Barthram and Grant (1984), Bircham (1981) and Milne et al (1982) have shown that, in vegetative swards, lamina is located in the top horizon of the sward, the depth of which increases as sward height increases. On day 0 the lamina component clearly occupied the uppermost sward horizons (Figure 4.14a) and during the first 4 weeks of the trial sward height was highly correlated with lamina mass across all treatments (Appendix Table 7.3c). However, coinciding with rapid stem elongation and inflorescence emergence, there was a good relationship between sward height and lamina mass only within 'control' groups and measurement periods (Appendix Figure 7.4). Hodgson and Maxwell (1982) commented that in reproductive swards the leaf and stem components become much more intermingled and swards will have a lower bulk density. The intermingling of lamina and stubble fractions is clearly seen in treatments M21, M28 and L14 (Figure 4.14e,f,g). However in treatments M7, M14 and H14 (Figure 4.14b,c,d), lamina remained at the top of the sward to a much greater extent. Bircham (1981) also found relatively little disruption to reproductive swards continuously grazed to below sward heights of 9cm.

Changes in canopy structure are clearly associated with changes in sward height (Figure 4.15a) during the treatment period as shown by the regressions of sward height with total and green herbage masses (Appendix 7). The data of Hodgson and Ollernshaw (1969), Milne et al

(1982) and Bircham (1981) also support the strong correlation between sward height and herbage mass. Davies and Calder (1969) found that changes in sward height closely followed reproductive development in spring, as shown by changes in mean reproductive apex length. Similarly, Wilman et al (1976a,d) found a close relationship between sward height and stem plus inflorescence mass and Wilman et al (1977) showed that length of stem was closely related to stem mass.

The profile on day 0 is a mean of four samples but unfortunately, due to time constraints, only one sample from replicate 2 was taken on day 83. A comparison of total, green, lamina, and stubble herbage mass and sward height with mean treatment values on day 83 is given in Table 5.5. In general there is good agreement between day 83 means and sample values except that lamina mass (with the exception of H14) was lower, and total herbage mass (primarily because of higher dead herbage content) of L14 was much higher, than expected in the stratified cut samples. Higher sward height in the stratified cut samples are because maximum sward height rather than mean sward height (as in day 83 measurements) was recorded.

5.4.3 Bulk Density

Table 5.5 Comparison of Sward Herbage Mass Components and Sward Height from Stratified Cut* and Dissection Samples** on day 83.

Component		H14	M14	L14	M7	M21	M28
		Treatment					
Total	stratified	2267	3192	8119	3258	4752	7307
	dissection	2225	3898	6214	3633	4909	6993
Dead	strat	387	1246	3168	1128	1734	2429
	diss	734	1346	1942	1172	1226	2172
Lamina	strat	1117	955	906	892	1230	1280
	diss	841	1234	1224	1084	1307	1685
Stubble	strat	763	991	4045	1238	1788	3598
	diss	650	1320	3050	1380	2380	3140
Height	strat***	14.0	20.0	65.0	12.0	55.0	57.0
	diss	8.5	15.0	43.2	9.3	30.9	35.8

* one sample only

** mean of four replicates

*** maximum sward height

Total sward bulk density (Table 4.7a) and the bulk density of lamina (Table 4.7b) of treatments L14, M21 and M28 were well below those of treatments M7, M14 and H14 by day 83. However, the lamina in swards L14, M21 and M28 tended to occur only in the middle strata of the sward so that individual canopy strata which contained significant proportions of lamina tended to have a much greater lamina density than that of the sward as a whole (Figure 4.14b-g)). Significant differences in lamina density were also recorded during the post-treatment period. However measurements of sward height included dead reproductive stem and therefore resulted in greater differences in lamina density between treatments than would probably have occured within the sward strata containing lamina.

5.5 EFFECT OF GRAZING MANAGEMENT ON HERBAGE ACCUMULATION

5.5.1 Total and Green

The response of total and green herbage accumulation to grazing management over the spring is very variable. For example, there were no differences in total or green net herbage accumulation (NHA) between treatments throughout the treatment period in this study (Figure 4.18). The results of Korte (1981) and Tainton (1974a)(after recalculation by Korte 1981) also show no difference in total NHA between swards defoliated at 95% light interception or two weeks after 95% light interception. However, Carton and Brereton (1983) found that lenient grazing (5-8cm) resulted in higher total herbage yeilds than severe (<5cm) grazing. Holmes and McClenaghan (1979) found that increased frequency of grazing (10 versus 21 days) appeared to depress growth rates especially when combined with less intensive grazing (1530 and 1940 kgDM/ha residual versus 1090 kgDM/ha residual). The maximum depression, however, was only 20%. Holmes and Hoogendorn (1985) found that during November herbage accumulation was greater with less severe grazing (H=56, M=71 and L=103 kgDM/ha/d) but in December the situation was reversed (H=55, M=31 and L=26 kgDM/ha/d).

A reduction in herbage accumulation because of severe grazing has been well documented (Brougham 1955,1956, Hunt 1970). There was no evidence in this trial to suggest that any reduction in NHA occured with treatment H14 (Figure 4.18). Similarly, Korte (1981) found an almost linear increase in herbage mass regardless of lax or hard grazing. The 'regrowth' curves of Brougham (1959) and Brougham and Glenday (1969) also show little or no reduction in NHA from severe grazing in spring. However Bircham (1981) found that under continuous stocking a severe reduction in net herbage production occured when swards were grazed below 700 kgDM/ha. There are two possible reasons for differences between rotational grazing and continuous stocking. H14 swards in this trial were grazed only to 1000-1200 kg total DM/ha (Figure 4.2d) rather than 500 kgDM/ha as were those of Bircham (1981). However residual LAI was lower in this trial (approximately 0.5 compared with 1.0) (Figure 4.17). The other reason may be due to the relative tiller density between hard grazing and other managements. Tiller density was reduced under very hard continuous stocking as a result of the uprooting of tillers by grazing sheep (Bircham and Hodgson 1983b). In contrast, vegetative tiller density of H14 was higher than M14 or L14 during most of the treatment period (Figure 4.8). Any tiller losses at the time of grazing must have been quickly recovered during the rest period.

5.5.2 Lamina and Stubble

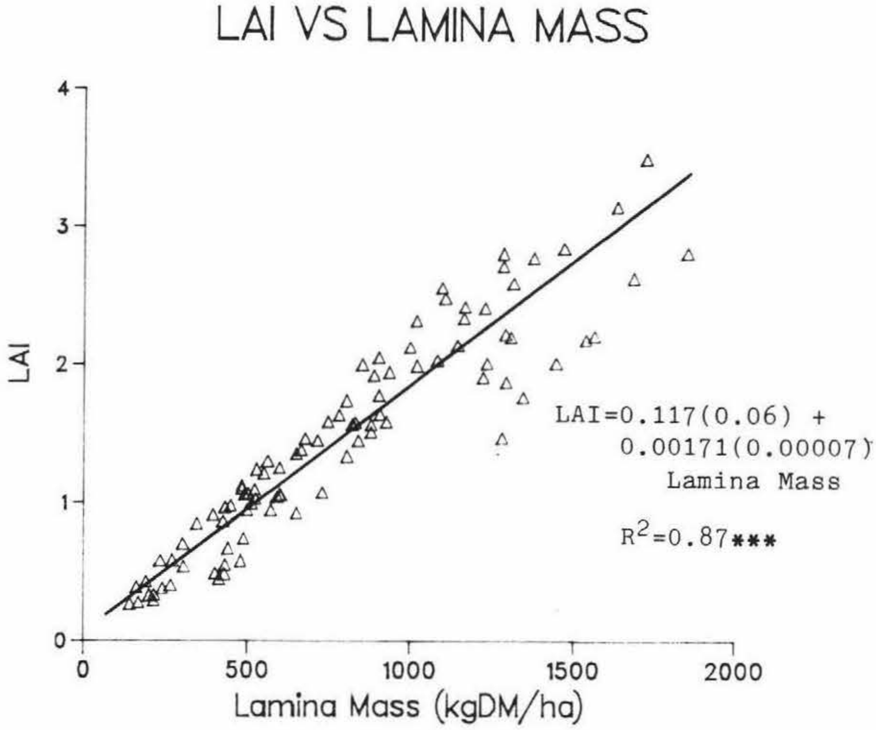
Green herbage accumulation is the result of the net herbage accumulation of lamina and stubble.

Reduced lamina accumulation on M21, M28 and especially L14 swards (Figure 4.19) is in agreement with results of others. For example, Carton and Brereton (1983) found no differences in lamina accumulation between lenient (5-8cm: equating to M treatments in this trial) and severe (<5 cm:

equating to treatment H14) grazing although the former had greater total herbage accumulation. Korte (1981) found that lamina accumulation was greater in hard than lax grazed swards and both Korte (1981) and Tainton (1974a) found that once 95% light interception was reached there was little further lamina accumulation. Wilman et al (1976a,c) also found that lamina accumulation was reduced by spelling intervals longer than 35 days. Bircham (1981) found, under continuous stocking, that swards grazed to 1700 kgDM/ha (6-7 cm, LAI=4) had a lower net lamina production than those swards grazed more severely (1000 kgDM/ha- 3 cm ,LAI=2-2.5). Total net herbage production though was similar between the two swards.

Calculation on the data of Brougham (1956) show that the increment in LAI was reduced 16% and 57% in regrowth over 32 days from defoliation to 7.5 cm and 12.5 cm respectively compared with 2.5 cm. Throughout this trial LAI was highly correlated with lamina mass (Figure 5.1) and differences in LAI increment almost certainly reflect differences in lamina accumulation. C. J. Hoogendorn (pers. comm.) found that, under dairy cow grazing, lamina accumulation was reduced by 60% and 84% on medium and lax grazed swards respectively compared with hard grazing, from November 22 to December 6. During the period February 15 to March 15 lamina accumulation on those swards was also reduced by about 50% compared with swards that were hard grazed over spring. It is

Figure 5.1 Relationship of Leaf Area Index (LAI) with Lamina Mass throughout the trial.



significant though that lamina accumulation during late October and November was not severely reduced by lax grazing as it was in this trial. However the length of spell was 20 days and the lamina accumulation of the M treatment may have been greater if a shorter interval had been used. Differences may, however, reflect differences between sheep and cattle grazing or season (drier conditions appeared to be experienced in the trial of Hoogendorn).

Swards M21, M28 and L14 produced 71% more ryegrass reproductive stubble (Figure 4.21) than did M7, M14 and H14. Lack of significance is probably due to the difficulties of sampling very long swards, especially after grazing on M21 and M28, when large numbers of animals were required to remove herbage and severe trampling resulted. The variation of stubble height and mass (clumpiness) in these swards also made representative sampling very difficult.

The size of reproductive tillers in swards M21, M28 and L14 was much greater than in swards H14, M7 and M14 (Figure 4.13) and individual reproductive tillers carried more lamina (and a greater LAI) both pre and post-grazing than did vegetative tillers or those of H14, M7 and M14 (Figure 4.10). Greater growth of these tillers is therefore expected (Grant et al 1981a) especially as greater numbers of primary reproductive tillers were left to mature (section 5.3).

In this trial the lack of differences in green herbage accumulation was a result of ryegrass reproductive stubble accumulation compensating for lower lamina accumulation in M21, M28 and L14. The inconsistencies in the response of net herbage accumulation to management in spring are likely to be as a result of differences in the rates of lamina and stubble accumulation. Korte (1981) concluded that differences found in NHA between hard and lax grazed swards were most likely due to reduced losses through death and decay in the former. While this is an important factor determining differences in lamina accumulation (as discussed later) it is probably not the main reason for differences over the spring and early summer until mature reproductive tillers die (Figures 4.21 and 4.22).

5.5.3 Lamina Growth

Lower lamina accumulation on L14, M21 and M28 swards may have arisen because of reduced lamina growth and/or increased lamina death.

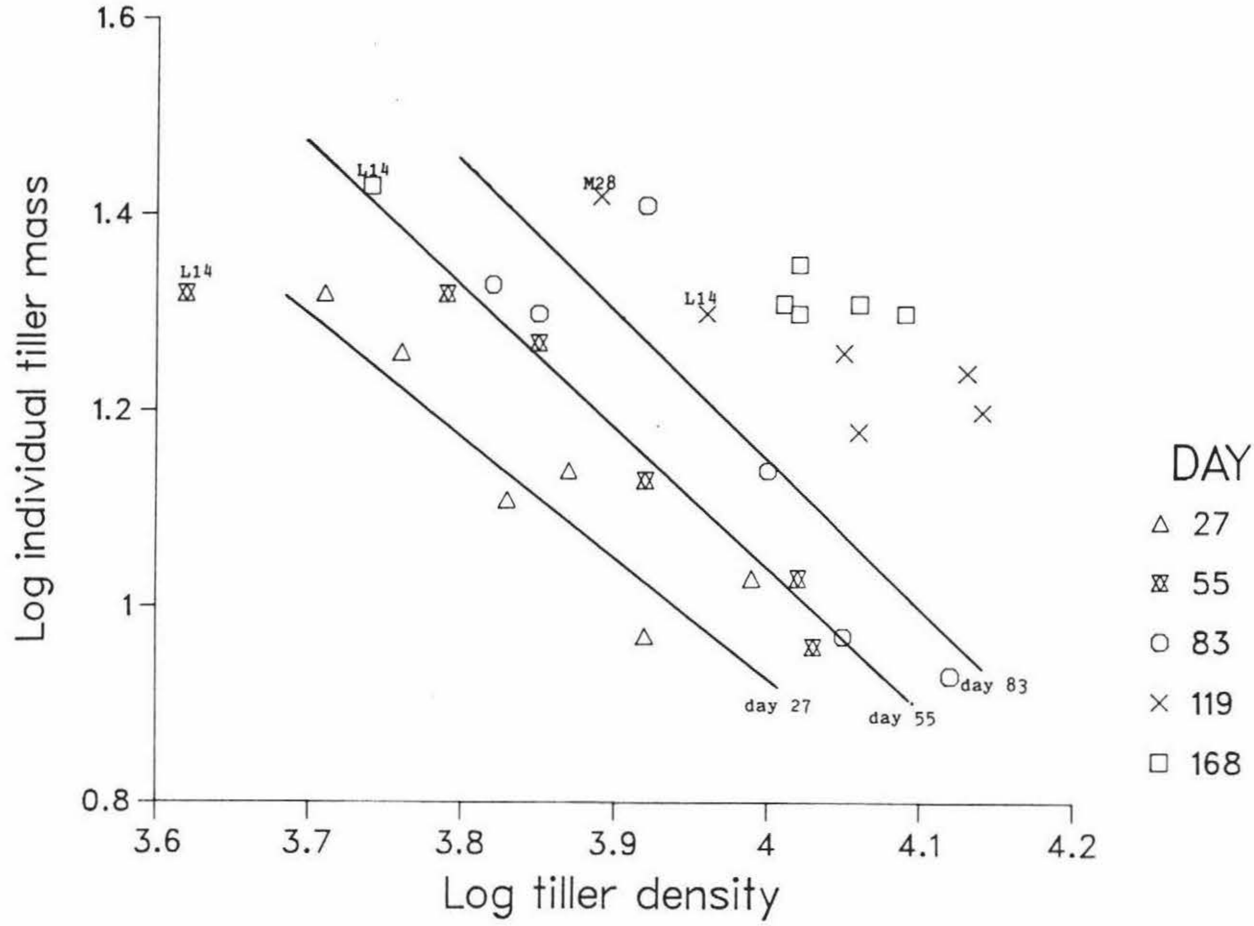
Lamina growth per hectare is dependent on both the growth of individual tillers and the density of those tillers (Bircham 1981). Management affects the lamina growth of individual tillers mainly through changes in the rate of leaf extension rather than leaf appearance (Grant et al 1981a, Davies 1974). Leaf extension rates are dependent on the lamina area of tillers (Grant et al 1981) and are generally greater on larger, older tillers (Carton and Brereton 1983, Bircham and Hodgson 1983b, Chapman et al 1984, Agyre and Watkin 1967). Both vegetative and reproductive tillers were larger in swards M21, M29 and L14 than in M7, M14 and H14 (Figures 4.8 and 4.13) and had greater lamina mass (and therefore LAI) per tiller both before and after grazing (Figure 4.10). It would be expected then, that lamina growth would be greater on both individual vegetative and, at least initially, in individual reproductive tillers of treatments M21, M28 and L14 than treatments H14, M7 and M14.

However, individual vegetative tiller mass and tiller density are usually inversely correlated with each other (Kays and Harper 1974, Bircham 1981). When the logarithm of tiller density and the logarithm of tiller mass are regressed a line of slope -3/2 is formed. This is known as the self-thinning line (Westoby 1984). This means that lamina growth per hectare may be similar between swards which have different lamina growth per tiller because lower lamina growth per tiller is compensated for by a greater tiller density.

Instability in the relationship between vegetative tiller density and individual tiller mass (i.e. deviation from the self-thinning line) has been found to result in depressed (Davies et al 1981, Bircham 1981, Bircham and Hodgson 1984) or enhanced (Bircham 1981, Bircham and Hodgson 1984) herbage growth depending on whether the deviation is below (depressed) or above (enhanced) the self- thinning line.

Growth of herbage at and after the time of inflorescence emergence has been found to depend on the size and/or density of the vegetative tillers (Jewiss 1972, Anslow 1965, Davies 1977, Davies et al 1981, Tallowin 1981). In this trial vegetative tiller mass and density were inversely related to each other on days 27, 55 and 83 (Figure 5.2). The slopes of the regression lines from a logarithmic plot were not significantly different from -3/2 (excluding L14 on day 55). During the period from day 28-55 vegetative tiller density in L14 fell rapidly whereas on all other swards a net increase in density occured (Figure 4.8). Despite a rapid increase, tiller size did not compensate for reductions in tiller density (Figures 4.9 and 5.2) and as a consequence lamina growth and (therefore) accumulation on L14 swards during this period was significantly reduced (Table 4.9). This reduction in tiller density was probably a result of both reduced tiller appearance and increased tiller death. Although tiller appearance normally resumes at

Figure 5.2 Relationship between the Logarithms of Individual Ryegrass Vegetative Tiller Mass and Ryegrass Vegetative Tiller Density on days 27, 55, 83, 119 and 168.



Regression Equations:

Day	27	Y=5.70(1.0)-1.19(0.26)X	r=0.89*	n=6
	55	Y=6.80(0.5)-1.44(0.14)X	r=0.98**	n=5*
	83	Y=7.18(1.5)-1.51(0.38)X	r=0.84*	n=6

where Y=log tiller mass
X=log tiller density

* excludes L14

inflorescence emergence (which occured during the period)(Langer et al 1964, Jewiss 1972), the poor light environment (Figure 4.16) associated with rapid stem elongation and increases in herbage mass (Table 4.1) and sward height (Figure 4.15) was probably not conducive to the release of tiller buds (Davies 1977, Ong 1978). Rapid tiller death also coincides with inflorescence emergence (Langer et al 1964) largely as a result of the failure of large flowering tillers to support the growth of young shaded vegetative daughter tillers (Ong et al 1978).

Similar results may have been expected in swards M21 and M28 as they had a large proportion of ryegrass reproductive tillers (Table 4.5) and reproductive herbage mass (Figure 4.6), and similar light interception before grazing (Figure 4.16). However grazing was harder and, timed just before inflorescence emergence, probably enabled vegetative tiller density to increase sufficiently at that critical stage so that vegetative lamina accumulation was not reduced by the same amount (Table 4.9).

Ryegrass vegetative lamina accumulation on swards L14, M21 and M28 was much reduced during days 0-27 compared with M7, M14 and H14 swards, and this was largely compensated for by increased lamina accumulation on reproductive tillers.

Unlike vegetative tillers, increased individual reproductive tiller mass (and growth) is reflected directly in increased growth per hectare as the density of reproductive tillers is relatively static over the short term (see section 5.3.2). Therefore increased reproductive lamina accumulation especially on M21, M28 and L14 swards, probably arose because of increased lamina growth per tiller (as lamina mass per tiller was greater- Figure 4.10) coupled with a similar or greater density of reproductive tillers (Figure 4.11).

Lower vegetative lamina accumulation on M21, M28 and L14 during days 0-27 probably arose because these swards had a lower proportion of vegetative tillers (Table 4.5) and reproductive tillers may have suppressed the growth of the vegetative tillers around them (Davies 1969) because they were larger and situated higher in the canopy (see Bircham 1981). The contribution of reproductive tillers to total lamina accumulation (Figure 4.20) fell after day 28. This is because although leaf appearance and extension are initially greater on reproductive tillers (Parsons and Robson 1980, Peacock 1975b, Thomas 1977, Vine 1983), lamina production must cease once the flag leaf has fully extended as leaf appearance ceases (Davies and Calder 1969).

Vegetative lamina accumulation on all plots was lower during period 3 than on H14. However, greater reproductive lamina accumulation on M14 swards during days 56-83 (probably due to the greater lamina growth of newly formed secondary reproductive tillers (Figure 4.10)), and greater white clover lamina accumulation on M7 swards (section 5.8), compensated for lower vegetative ryegrass lamina accumulation.

5.5.4 Lamina death

Lamina death is also greater on larger tillers (Carton and Brereton 1983, Bircham and Hodgson 1983b) and net lamina production may be similar (Wilman and Shrestha 1985) or reduced (Bircham 1981) on swards of high compared with low herbage mass. Lamina death is proportional to herbage mass (Hunt 1970, Bircham 1981). As greater average green and lamina mass occured on swards of L14, M21 and M28 (Figure 4.1), greater lamina death is expected. Greater death would also be expected due to longer lengths of spell in M21 and M28 than M7 and M14. Grant et al (1983) recommended that that swards be defoliated within one leaf appearance interval so that leaf death is minimised. In spring the leaf appearance interval is between 12 and 18 days (Hunt and Field 1978, Jones et al 1982, Vine 1983, Chapman and Clark 1984).

Lamina remaining after grazing on swards M21, M28 and L14 was most likely older than that on H14, M7 and M14 and was more likely to die before the subsequent grazing (Carton and Brereton 1983).

5.6 EFFECT OF GRAZING MANAGEMENT ON SUBSEQUENT PASTURE PERFORMANCE

Korte (1981), McDonald (1983), Sheath et al (1984) and Sheath and Boom (1985) have all demonstrated that subsequent net herbage accumulation may be greatly reduced as a result of lax grazing during spring. In this trial the very large differences in both total and green herbage accumulation (Figure 4.18) during the post-treatment period were mostly due to the death and disappearance of reproductive stubble (Figures 4.21 and 4.22) rather than differences in the accumulation of new tissue.

Differences in the latter are better demonstrated by the accumulation of lamina. Reduced lamina accumulation on all swards (especially M21, M28 and L14) from days 85-119 compared with H14 may have been due to the greater amounts of lamina on all plots compared with H14 after grazing on day 85 (Table 4.2a) which would almost certainly have died before the following grazing. As grazing height is increased greater numbers of aerial tillers occur and tiller apices are generally elevated within the canopy (Jackson 1974, Korte 1981). Greater numbers of tillers would probably have been removed from all swards compared with H14 on days 83-85, thus lowering potential regrowth. During days 56-83 white clover contributed significantly to the lamina accumulation of M7 (Figure 4.20). However from days 85 to 119 no differences existed between M7 and other treatments. Reduced lamina accumulation of M7 may have been as a result of the removal of stolon tips at the hard grazing on days 83-85. If that grazing had been less intense greater lamina accumulation may therefore have occured on M7 over days 85-119.

Figure 5.2 indicates that disturbances to the individual tiller mass/ tiller density equilibrium in treatments M28 (day 119) and L14 (days 119 and 168) may have been the major reason for lower lamina accumulation in those swards. Korte (1981) found that subsequent summer performance on lax grazed swards was reduced during dry but not moist seasons and the results of Korte and Chu (1983) and Barker et al (1985) suggest that this may be due to recovery of tiller density over summer. Korte (1982) found that differences in tiller density between swards that were hard or lax grazed in spring were still apparent in early winter. Sheath and Bircham (1983) recommended that removal of surplus herbage should be done as soon as possible to ensure rapid recovery of lax grazed swards. The summer of this trial was relatively moist (Appendix 1) and therefore rapid recovery of tiller density would have been expected. However sufficient herbage might not have been removed on days 83-85 to enable rapid tiller recovery. In fact very little of the reproductive and dead herbage that had accumulated over the treatment period was removed from M21, M28 and especially L14 swards (Figure 4.1), illustrating the difficulty of removing this material with grazing animals once it has accumulated.

5.7 EFFECT OF GRAZING MANAGEMENT ON DIGESTIBILITY AND DEAD HERBAGE CONTENT

The proportion of dead herbage in the sward is the main determinant of sward organic matter digestibility (OMD) (Rattray 1978a,b, Korte 1981, Francis and Smetham 1984). In late spring and summer the maturity of reproductive stem, especially after inflorescence emergence, influences digestibility (Browse et al 1981, 1984, Terry and Tilley 1964, Raymond 1969). The OMD of green lamina and leaf sheath is very similar in vegetative pastures (about 0.8) but the latter may decline in a similar manner to reproductive stem though at a lesser rate (Terry and Tilley 1964). At day 83 there were no significant differences in OMD between treatments (Table 4.8). Although the proportion of dead herbage in total herbage mass (Figure 4.7) was very similar in all swards, differences in the proportion of ryegrass reproductive stubble (Figure 4.6) would have been expected to result in differences in OMD, especially as a high proportion of M21, M28 and L14 inflorescence had emerged at least a month earlier (day 55- Figure 4.12). However, differences in the OMD of reproductive and vegetative ryegrass stubble were small (5%) (Table 4.8) and would not be large enough to cause a marked decline in the OMD of the whole sward.

Sward OMD was not measured on days 119 and 168. However large differences in the proportion of dead herbage on those days (Figure 4.7) would undoubtably result in large differences in OMD (Rattray 1978a) especially between treatments M7, H14, M14 and treatments M28 and L14.

Korte et al (1982, 1984) also found that ryegrass reproductive tillers died over the December to Februaury period and large differences in dead herbage between hard and lax grazed swards resulted. Campbell (1966) found very similar differences in dead herbage between swards grazed by dairy cows at high and low stocking rates. Their results indicate that differences in dead ryegrass reproductive mass between treatments may have remained until May-July, despite harder grazing pressures in the autumn and winter.

5.8 EFFECT OF GRAZING MANAGEMENT ON BOTANICAL COMPOSITION

Ryegrass was the dominant species throughout the trial (Figure 4.2), typical of a developed, high fertility sward (Boswell and Crawford 1978). Poa spp came into prominence in two situations. The first was after day 49 in the treatment period when the content of Poa on all treatments increased substantially and then declined by day 83. The second was the greater Poa content in M7 swards than other treatments especially about day 83. Wells and Hagar (1984) have shown that Poa annua is not an aggressive species but one very adept at colonizing swards where the competitive ability of ryegrass was low. In the first case this happened after the main period of reproductive development in ryegrass (days 28-55) and in the second the vigor of ryegrass may have been reduced by frequent grazing which, combined with relatively low light interception (Figure 4.16) (Bircham 1981), allowed Poa spp to ingress.

White clover is also a species whose competitive ability is very much poorer than ryegrass (Harris and Thomas 1973, Rhodes and Ngah 1983, Martin and Field 1984), and Ennick (1970) postulated that clover is more or less bound to the space left by grass in the canopy.

The yeild of white clover in a mixed sward is determined by the density of stolon tips (growing points)(Hay and Baxter 1983), mass, diameter or length of stolon (Hay 1983, Wilman and Aseigbu 1982). Stolon development is promoted by light (Beinhart 1963, Woledge and Dennis 1982) and by reasonable, but not high, temperature (Beinhart 1963). The spring period is an important period of stolon development and may have a large influence on summer white clover production (Hay and Baxter 1984).

As a result of greater stolon tip density (Table 4.4), white clover lamina accumulation on M7 swards was much greater than that of any other treatment during the treatment period, especially days 56-83 (Figure 4.20). This was reflected in greater pregrazing white clover lamina mass (Table 4.4), and a greater proportion of white clover in total lamina mass (Figure 4.2). White clover stolon tip density on H14 at the end of the treatment period was not high. This was unexpected in view of the high stolon tip density on M7 especially as pregrazing light interception (Figure 4.16) was similar to that of M7. Lancashire and Keogh (1968) found that sheep under hard grazing (2.5- 5.0 cm) removed far more white clover stolon material than when grazing to 8-10cm. For this reason stolon tip density may have been reduced on hard grazed swards.

As previously mentioned hard grazing at the end of the treatment period was probably the cause of lowered clover accumulation especially on M7 during days 85-119 (Appendix Table 3d). However, after hard grazing on day 85 white clover stolon tip density was significantly higher on M7 than all other treatments (1830 vs 250-690 stolon tips per M2- Appendix Table 4d). Both Sheath and Bircham (1983) and Hay and Baxter (1984) have found that hard summer grazing (especially continuous stocking) is deterimental to white clover production during summer. The long (34 day) spell between grazings and the use of a moderate grazing intensity on days 119-120 probably ensured higher white clover accumulation over the following period (days 120-168) on H14 and M7, which both had higher stolon tip density by 168 (Table 4.4) than other treatments. It is significant that white clover production was depressed on those treatments which had a high accumulation of reproductive stubble during the spring (i.e treatments M21, M28, and L14). Similar results were reported by Sheath and Bircham (1983) and Sheath and Bryant (1984) especially when summer grazing was hard.

The production of stolon mass is extremely sensitive to the light environment (Hay and Baxter 1984) as was shown on M14 plots which also had lower clover production throughout the trial though a high accumulation of reproductive stubble did not occur. Hay and Baxter (1984) found that set stocking in spring resulted in greater white clover accumulation under monthly grazing in summer than 2 week (44%) and especially 3 or 4 week (>100%) rotational grazing during spring. Spring grazing was hard (1-2 cm) and no differences in spring white clover production were recorded. Results of this trial suggest that had grazing been slightly less severe (e.g. 6 cm) then greater spring accumulation under continuous stocking may have resulted, but accumulation in the 2 week rotational grazing treatment may have been poorer during summer.

5.9 IMPLICATIONS FOR ANIMAL PERFORMANCE

It has long been recognised that pasture 'quality' in late spring is dependent on grazing management and that losses in animal performance arise from the lowering of pasture 'quality' (Davies 1960, Lewiss and Cullen 1964, Smeaton 1983). Animal intakes and performance usually increase with increasing herbage mass, allowance or sward height (Hodgson 1977,1982, Rattray and Clark 1984). However in late spring and summer reduced intakes have been found with both cattle and sheep with greater herbage masses (Greenhalgh et al 1966, Hodgson and Wilkinson 1968, Reardon 1977, Langlands 1977, Hughes 1983). On the other hand Large and Spedding (1957) and Jagusch et al (1979) found no difference in growth rates of lambs grazing pastures of high or low herbage mass.

5.9.1 Importance of leaf lamina

Pasture quality has traditionally been described in terms of organic matter digestibility (OMD) (Blaxter et al 1961, Holmes and Hoogendorn 1985). However, changes in OMD are largely a response to changes in the proportion of dead herbage but animal performance is unrelated to the dead content of pastures and much more closely related to green than total herbage mass or allowance (Rattray and Clark 1984). The composition of animal intake is largely green leaf (Guy et al 1981).

There is strong evidence that differences in animal performance when grazing reproductive pastures are due primarily to the quantity of leaf lamina in the sward and ,secondly, to the relative quantities and distribution of lamina and stubble.

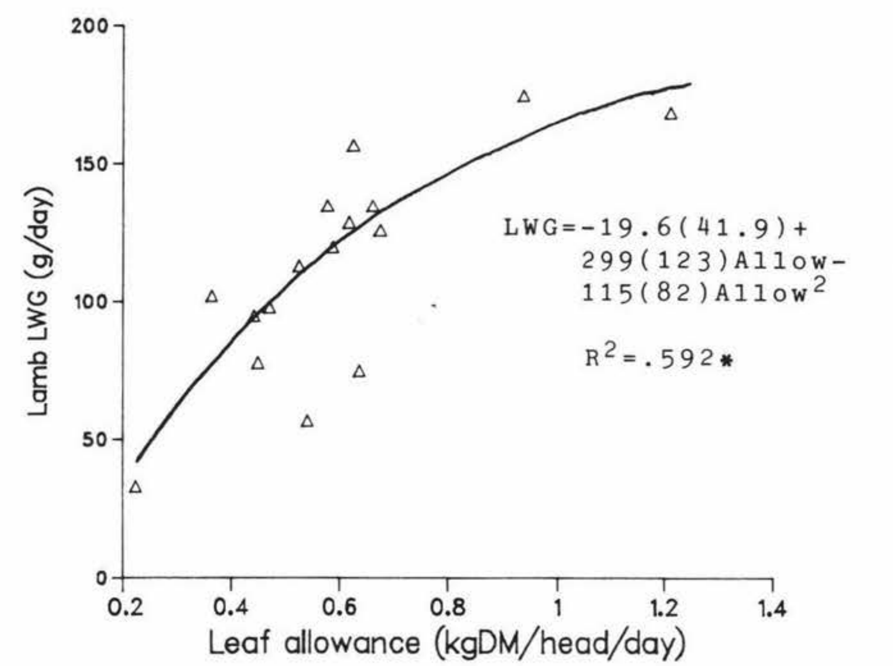
It has long been recognised in tropical swards that the amount of leaf tissue available determines animal intake and performance (Stobbs 1973, 1975, Chacon and Stobbs 1976, Stobbs and Hutton 1974, Hendrickson and Minson 1980). Barthram (1980), Barthram and Grant (1984) and Milne et al (1982) have shown that herbage intake is related to the depth of the leafy sward horizon. Barthram and Grant (1984) suggest that whole-sward parameters are important only because it is through them that the characteristics of the lamina fraction of the sward can be manipulated.

Calculations using unpublished data of M.A. Richardson and C. C. Bell (M.A.F Research Division, Batchelor House, Palmerston North) from an experiment where lambs rotationally grazed pastures which were either 'uncontrolled', topped or sprayed with Mefluidide or Paraquat to reduce reproductive development show that liveweight gains were related to the allowance of lamina (grass lamina and total clover) (r^2 =0.59) (Figure 5.3) but not to the allowance of green (r^2 =0.00) or total (r^2 =0.00) herbage.

Thomson et al (1986) also found a positive correlation between ewe and lamb liveweight gains from docking to November but a negative one during November/December when animal performance was positively influenced only by the green leaf content of the pasture. Very similar results were obtained by C.J. Hoogendorn (pers. comm.) with dairy cows. It was found that the relationship between intake and lamina allowance was very much better than between intake and green or total herbage allowances. This may account for the lack of correlation found by Thomson et al (1984) between milk fat production and the stem content of pastures.

Bircham (1982) suggested that in reproductive swards interruption of the leafy horizon at the top of the sward is likely to force sheep to adopt a more selective grazing pattern and as a consequence reduce intake. The results

Figure 5.3 Relationship between Lamb Liveweight Gains in Early Summer and Leaf Lamina (Ryegrass Leaf plus Total Clover) Allowance (from unpublished data of M.A. Richardson and C.C. Bell)



of Hughes (1983) and Hughes et al (1984) seem to support this suggestion.

However Butler (unpubl. data) found no evidence for reduced liveweight gains of set stocked ewes and lambs in late spring when lamina mass remained high (about 1000 kg lamina DM/ha) on pastures in which much reproductive development occured. After the conclusion of the trial there was, though, a strong preference by sheep to graze those swards on which reproductive development was minimized.

The extent to which reproductive stem interferes with the attainment of high (lamina) intakes may therefore be dependent on the severity of grazing, the grazing system (i.e. set stocking vs rotational grazing, structure of the sward (i.e. relative positions of lamina and stubble and extent of reproductive development, e.g density of reproductive stems) and species composition. There is an obvious need for further research in this area.

It would appear then, that pasture quality is largely determined by the the quantity of leaf mass or allowance, that is, "leaf quantity is pasture quality", probably modified under certain sward conditions by the presence of reproductive stubble.

The implications to animal performance from the findings of this study seem quite clear. There is strong evidence to suggest that sheep performance from the 'uncontrolled' swards (especially L14) would have been much lower than from M7 and M14 throughout the trial and also from H14 at least over the post-treatment period assuming equitable grazing intensity. This would be due to both reduced lamina accumulation (Figure 4.19) (meaning either lower lamina mass and lower per head performance or lower stocking rates) and greater content of reproductive stubble (Figure 4.1) and lower L:S ratios (Figure 4.3) in the former.

There are three other reasons why differences in animal intakes may occur. The first is that in M21 and M28 swards, difficulty was experienced over the treatment period to reduce lamina content to that desired, despite large numbers of sheep and a relatively short grazing period. This appeared to be due to severe trampling and perhaps fouling of the swards so that lamina was 'trapped' within a matt of trampled stem. Similar difficulties were experienced at the day 83-85 hard grazing.

Secondly, lamina density on L14 during the treatment period was close to that expected to reduce the intake per bite of grazing sheep (Hodgson and Maxwell 1982). This effect may be more pronounced as the total amount of lamina in the sward declined. The third reason is that there was a higher proportion of white clover in swards M7 and H14 (during the post-treatment period) would also be expected to result in greater stock growth (Archer 1980, Thomson 1977) on these than on other treatments.

5.9.2 Modelling grazing systems

It must also be concluded that modelling lamina (grass and clover), and perhaps reproductive stubble, accumulation and animal intake must be a prerequisite to effectively modelling grazing systems over the spring and summer.

Bircham (1981) simulated continuous stocking over 30 weeks from early spring and evaluated the use of both green and lamina herbage as the basis for decision making over the spring and summer (i.e. over the period of ryegrass reproductive development). It was concluded by Bircham (1981) that 'lamina mass is likely to be a better index upon which to base management decisions than either herbage mass or green herbage mass'. This statement is supported by McCall (1984).

Johnson and Parsons (1985) and Sheehy et al (1979, 1980) have also modelled lamina accumulation under continuous grazing and for regrowth from defoliation respectively. The latter did not include the grazing animal and no account was taken of the effect of changes in tiller density/individual tiller mass in these models. However, in no other grazing systems model (Noy-Meir 1978, Freer et al 1970, Vickery and Hedges 1972, Arnold and Campbell 1972, Arnold et al 1977, Barlow 1985, Christian et al 1978, McKinney 1972, Hutchinson 1972, White et al 1979, 1983, White and Bowman 1984, Wright and Baars 1976, Baars 1980, McCall 1984, Field et al 1981), herbage production models (Edelstein and Corrall 1979) and feed budget computer programmes (Milligan 1982) has the accumulation of lamina and use of lamina for prediction of animal intakes and performance been used.

A successful model of lamina accumulation under grazing must be dynamic, include both continuous stocking and rotational grazing and include both vegetative and reproductive pastures. To do this tiller dynamics, leaf appearance and extension, leaf duration, and number of leaves per tiller would probably have to be modelled (see Vine 1983). To the authors knowledge this has not yet been attempted.

There are several computer models which successfully predict 'rate of growth' trial pasture accumulation (Baars et al 1984, J.S. Bircham pers. comm.). These may be a source of information, over a wide range of environments, on potential lamina accumulation.

It is uncertain to what extent 'rate of growth' trials express differences in lamina, stubble and dead herbage accumulation. However, trim techniques (which are most commonly used- Radcliffe 1974) may minimize differences due to reproductive stubble and dead herbage because these components are removed from above cutting height, and any reproductive tillers with meristems above cutting height killed, before the start of the measurement period. Four weekly cutting may generally have greater herbage accumulation during spring than two weekly cutting (Baars 1982) because a greater proportion of accumulated herbage is reproductive stubble.

Support for this view was found during this study. Net herbage accumulation under monthly cutting, using small cages, was measured by M.A.F. Advisory Services Division staff from Batchelor Agricultural Centre (P.N.) in conjunction with this study. Results are given in Appendix 6. During the treatment period total net herbage accumulations were much lower than measured under grazing but results appeared to be much more closely related to lamina accumulation than to either green or total herbage accumulation over the complete measurement period.

Adequate prediction of lamina accumulation under grazing may be possible by adjusting 'rate of growth' trial data for differences in lamina accumulation found under different management criteria, such as those established in this study.

5.10 IMPLICATIONS FOR SPRING MANAGEMENT

From the previous discussion it is obvious that the changes in the pastures over spring and summer were a direct result of the managements imposed. The results of this study should enable grazing criteria to be established which will aid decision making in the spring so that pasture and animal performance is optimized.

5.10.1 Grazing Criteria

In a series of experiments Korte (1981) studied the value of using different sward characteristics as the criteria on which to base grazing decisions. The sward characteristics studied were light interception (before grazing), stage of reproductive development and tiller density. It was concluded (Korte et al 1982b) that 'spring management of ryegrass dominant pasture to control reproductive development of the sward was a more important criteria than management to control leaf area and light interception'. The results of this trial support this conclusion. It is suggested that control of individual reproductive tiller mass is probably the means (or criteria) by which control of reproductive development can be carried out, rather than reproductive tiller density which has previously been suggested (Korte 1981, Hughes

1983, Smetham 1983). Individual tiller mass is, however, not very easily measured in the field and therefore could not itself be used as a practical grazing criteria. Pregrazing pasture height or herbage mass (total and green), and emerged inflorescence density are all highly correlated with individual reproductive tiller mass (Table 5.4). They are all easily measured (especially if a Pasture Probe is used to measure herbage mass- see Appendix 7) but only pasture height or herbage mass would be effective grazing criteria.

The reason for this is because emerged inflorescence density can only be measured after pasture 'control' has been determined though it may aid decisions such as whether topping is likely to be of benefit (McDonald 1984). One difficulty with the use of 'seedhead' density is its variability. For example, McDonald (1984) found that topping was beneficial on pastures which had 2000 but not 500 seedheads per m2. The results of this trial suggest that topping may have been beneficial on M21 and M28 swards which had only 380 and 530 seedheads per m2 (respectively) by day 83.

5.10.2 Practical Spring Management

Sheath et al (1984) have stated that "correct management should be a compromise between high feed offer and restricted selective grazing so that control of pasture quantity and quality is not lost'.

Korte (1982), Korte et al (1982b), (1984), Hughes (1983) and Smetham (1983) have all upheld the view that a well timed hard grazing in spring is the management required to maintain or regain good sward condition. But hard grazing cannot be recommended. Although this management is of benefit to the sward (Korte 1981) it is also clear that, if used in a farm system, large losses in animal production will result (Rattray et al 1982). Smeaton (1983) has recommended that for ewes and lambs 'every effort should be made to maximise pasture intake THROUGHOUT lactation'. There is a further risk in the use of hard grazing. During spring total net herbage accumulation is usually much greater than herbage consumption. Hard grazing, by reducing herbage consumption further, increases this imbalance and leads to greater spells between grazing. As a result, the quality of pregrazing herbage deteriorates and this may lead to even lower intakes.

The results of this study suggest that, on high fertility ryegrass/white clover pastures, the compromise between pasture quality and quantity may not be as large as Sheath et al (1984) imply.

Pasture 'control' was maintained on treatments which had residual lamina of less than approximately 500 kgDM/ha and a spell between grazings of 14 days or less. These treatments were grazed to a sward height of 6-9 cm from a pregrazing height of less than about 20 cm (Figure 4.15a). These are equivalent to pregrazing green herbage mass of 2700-3000 kgDM/ha (Table 4.1f) and residual green herbage mass of 1400-1600 kgDM/ha (Table 4.2c).

These grazing levels are those likely to give 80-90% of maximum ewe and lamb growth rates (Rattray et al 1982, B. M. Butler unpubl. data, Bircham 1981) throughout lactation.

Sheath and Bryant (1984) also suggested that optimum residual herbage mass during spring was 1300-1600 kgDM/ha under dairying in the Waikato (though these figures are total rather than green herbage mass). Maxwell (1983) concluded that grazing to below 1800 kgDM/ha (probably about 7 cm, Bircham 1981) was required to 'remove stem and inflorescence early in development'. Sheath and Bircham (1983), however, suggest that hill country sheep should be set stocked at 3 cm height (1800 kgDM/ha) or quickly rotated (<20-25 days) to 4-5 cm residual to maintain pasture control. Differences in measuring height (G. W. Sheath pers. comm.) or greater difficulty (and therefore the need for lower residuals) in 'controlling' steeper, lower fertility land may be reasons for the differences.

The latter may be due to the greater content of annual grasses in the sward, or because pastures are generally stocked at lower rates and therefore individual tillers are grazed less frequently. However, the rotation lengths suggested by Sheath and Bircham (1983) are of a length that, in this trial, enabled reproductive tillers to emerge and develop without being defoliated by the sheep. Perhaps if these were shorter then the residuals recommended for hill country could then be slightly higher.

5.11 SUGGESTIONS FOR FURTHER RESEARCH

One of the aims of pasture and animal research is to provide information on the effects of different management on the physical performance and net financial returns of a farm system. Because of the complexity of farming systems and animal/pasture interactions, and the increasing costs of research, the use of simulation models are essential to understanding these effects. They are also an invaluable aid in identifying the strengths and weaknesses of a system and the opportunities for change, especially as changes in the physical and financial aspects of farming can be very rapid.

As has been discussed, current models are unlikely to adequately simulate sheep grazing in New Zealand over the spring and summer periods. This period is critical as most animal liveweight gains occur during this time and critical management decisions (e.g. pasture 'control' and ewe and lamb feeding for wool and meat production) are being made. It is therefore important that a close examination of current models is carried out and that if this view is supported a model based on the flow of lamina rather than total or green herbage is constructed.

This study has identified several areas where further research is required to aid the understanding of management effects on pasture and animal performance.

These areas are:

1. The effects of management and environmental factors on the magnitude and repeatability of lamina accumulation over spring and summer.

2. The relationship between total, green, and lamina accumulation and the effect of management on these relationships.

3. Differences between ryegrass/white clover and annual grass swards in reproductive development and in 1. and 2. above.

4. The effect of winter severity and frequency of grazing on spring lamina accumulation.

5. The effect of level of pasture cover at lambing on the level of surplus pasture and 'control' in late spring and summer.

6. Differences in herbage accumulation (and its components) resulting from cutting (especially 'rate of growth') and grazing trials including 1., 2. and 3. above.

7. Definitive studies on the influence of lamina and reproductive stubble (live and dead) on the intakes and performance of grazing sheep and cattle throughout the year.

CHAPTER 6 CONCLUSIONS

The conclusions of this study are:

1. Pasture 'control' was maintained on swards M7, M14 and H14 but not on L14, M21 and M28. These differences may be considered as absolute.

2. Differences between swards in pasture 'control' were largely due to differences in ryegrass reproductive stubble and its effects on sward structure (especially the proportion of lamina), tiller density/individual tiller mass relationships, lamina accumulation and botanical composition.

3. The individual mass of reproductive tillers was the most important factor determining differences in ryegrass reproductive stubble.

4. Because of their correlation with individual reproductive tiller mass, herbage mass (total or green) and sward height are the most practical criteria on which to base spring grazing management.

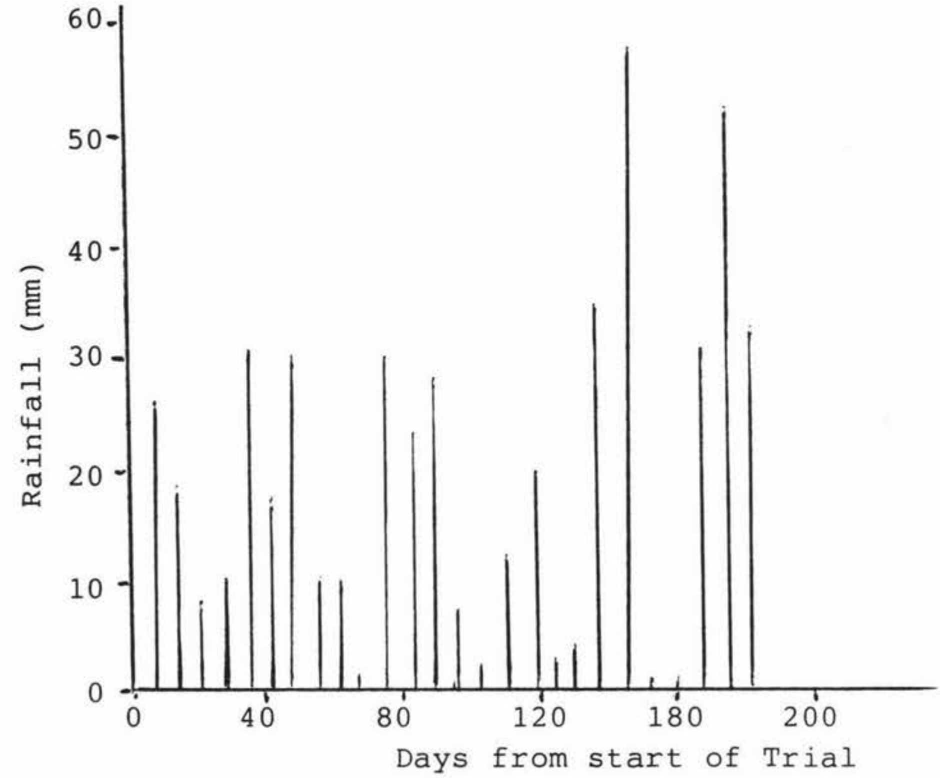
5. Greater 'risk' of poor lamina accumulation over summer and autumn was associated with lack of pasture 'control'

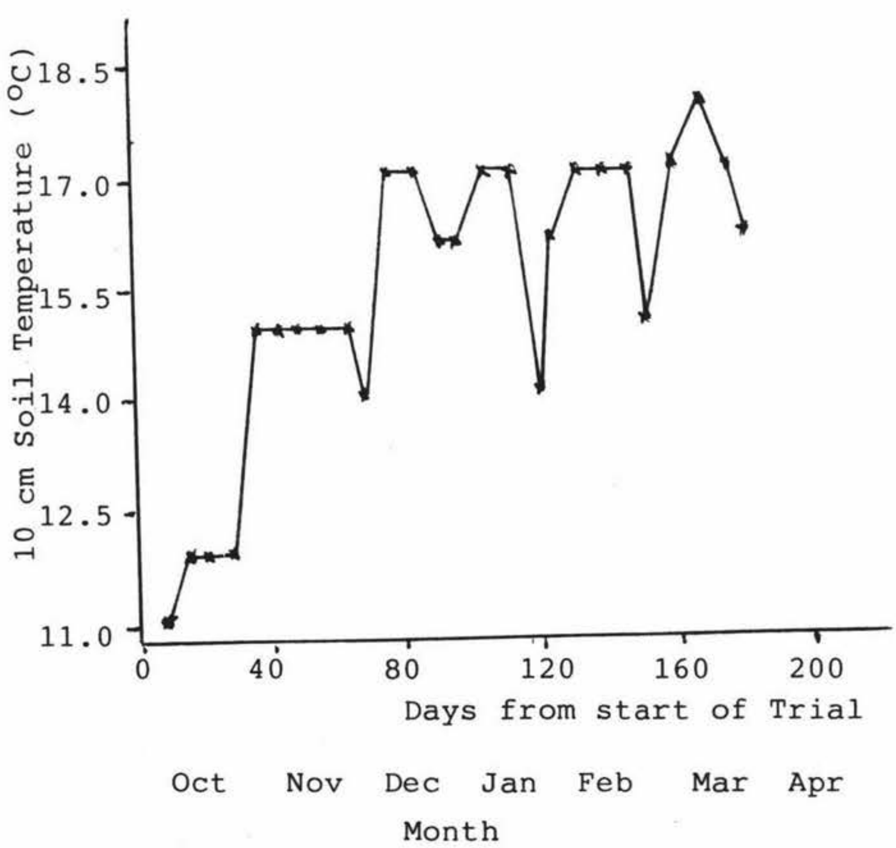
and this was largely influenced by the recovery of tiller density.

Appendix 1 Comparison of 40 year Monthly Rainfall and 10cm Soil Temperature Means with actual 1983/1984 monthly means (D.S.I.R., Palmerston North)

Month	Rainfall (mm)		10cm Soil Temp (^{o}C)	
	40 Year	1983/1984	40 Year	1983/1984
August	89	65	7.6	8.1
September	75	107	9.9	10.4
October	88	72	12.5	13.0
November	78	54	15.1	14.8
December	94	87	17.3	16.5
Januaury	79	36	18.5	16.2
Februaury	67	92	18.1	16.5
March	69	33	16.3	16.0
April	81		13.2	
May	89		10.1	
June	97		7.7	
July	89		6.7	

Appendix 2 **Mean Weekly Rainfall and 10cm Soil Temperature for the Duration of the Trial (from D.S.I.R., Palmerston North)**





Appendix 3 Tables of sward characteristics: means and relevent statistics.

Appendix Table

3a Percentage a) ryegrass, b) white clover and c) other grasses in pregrazing herbage mass

3b Percentage a) ryegrass, b) white clover and c) other grasses in pregrazing lamina mass

3c Other grasses a) pregrazing lamina and b) total herbage masses (kgDM/ha) and c) tiller density (tillers/m^2)

3d White clover a) pregrazing lamina mass (kgDM/ha) and b) stolon tip density (incl. day 85) (stolon tips/m^2)

3e Leaf:Stem ratio (L:S) a) pregrazing and b) post-grazing

3f Percentage ryegrass reproductive stubble in a) total ryegrass, b) green and c) total herbage masses

3g Mean lamina mass per a) vegetative and b) reproductive ryegrass tiller, both i) pregrazing and ii) post-grazing, over the treatment period (mg/tiller)

3h Leaf area index (LAI) a) pregrazing and b) post-grazing

Appendix Table 3a Percentage a) Ryegrass, b) White Clover and c) Other Grasses in Pregrazing Green Herbage Mass.

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Ryegrass							
27	88 a	88 a	89 a	79 a	88 a	87 a	90 a
55	84 a	78 a	80 a	81 a	78 a	89 a	88 a
83	86 b	90 b	91 b	60 a	90 b	90 b	90 b
119	82 a	92 a	88 a	83 a	92 a	90 a	95 a
168	84 ab	95 c	85 ab	80 a	95 c	91 bc	94 bc
b) White Clover							
27	3 a	4 a	5 a	9 a	4 a	4 a	5 a
55	5 a	4 a	3 a	11 a	4 a	4 a	5 a
83	4 a	5 a	3 a	23 b	5 a	5 a	8 a
119	10 a	4 a	9 a	10 a	4 a	6 a	4 a
168	13 bc	3 a	8 ab	18 c	3 a	7 ab	5 a
c) Other Grasses							
27	8 a	7 a	6 a	11 a	7 a	9 a	5 a
55	11abc	18 c	17 bc	8 ab	18 c	6 a	7 a
83	9 b	5 ab	5 ab	16 c	5 ab	5 ab	1 a
119	6 a	4 a	3 a	7 a	4 a	4 a	1 a
168	2 a	2 a	6 a	3 a	2 a	1 a	1 a

Appendix Table 3b Percentage a) Ryegrass, b) White Clover and c) Other Grasses in Pregrazing Lamina Mass.

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Ryegrass							
27	90 a	88 a	92 a	81 a	88 a	89 a	92 a
55	85 a	81 a	82 a	81 a	81 a	90 a	87 a
83	88 b	92 b	90 b	70 a	92 b	91 b	96 b
119	88 a	94 a	93 a	86 a	94 a	93 a	97 a
168	90 ab	95 b	91 b	86 a	95 b	94 b	96 b
b) White Clover							
27	3 a	5 a	4 a	10 a	5 a	3 a	4 a
55	6 a	4 a	3 a	11 a	4 a	4 a	6 a
83	4 a	5 a	5 a	20 b	5 a	5 a	3 a
119	7 a	3 a	5 a	10 a	3 a	4 a	3 a
168	9 ab	3 a	7 ab	12 b	3 a	5 a	3 a
c) Other Grasses							
27	7 a	7 a	4 a	9 a	7 a	8 a	4 a
55	9 a	15 a	15 a	8 a	15 a	6 a	7 a
83	7 a	4 a	5 a	10 a	4 a	4 a	1 a
119	5 a	3 a	2 a	4 a	3 a	3 a	0 a
168	1 a	2 a	2 a	2 a	2 a	1 a	1 a

Appendix Table 3c Other Grasses a) Pregrazing Lamina and b) Total Herbage Masses (kgDM/ha) and c) Tiller Density (tillers/m^2).

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Lamina Mass							
27	60 a	100 a	50 a	80 a	100 a	120 a	70 a
55	100 a	180 a	170 a	60 a	180 a	70 a	110 a
83	60 a	40 a	70 a	100 a	40 a	60 a	20 a
119	90 a	40 a	30 a	60 a	40 a	40 a	0 a
168	10 a	30 a	20 a	30 a	30 a	20 a	20 a
b) Total Herbage Mass							
27	120 a	210 a	160 a	180 a	210 a	250 a	170 a
55	220 a	490 ab	710 b	160 a	490 ab	190 a	270 a
83	130 a	120 a	200 a	380 b	120 a	160 a	60 a
119	190 a	90 a	90 a	200 a	90 a	100 a	20 a
168	40 a	50 a	110 a	70 a	50 a	40 a	40 a
c) Tiller Density							
27	1170 a	1340 a	980 a	2160 a	1340 a	1580 a	1290 a
55	2260 a	3910 a	1480 a	1350 a	3910 a	2150 a	2220 a
83	2140 a	1150 a	1310 a	5160 b	1150 a	1770 a	640 a
119	3390 a	2100 a	930 a	2230 a	2100 a	1400 a	290 a
168	410 a	510 a	1220 a	930 a	510 a	690 a	720 a

Appendix Table 3d White Clover a) Pregrazing Lamina Mass (kgDM/ha) and b) Stolon Tip Density (including day 85) (stolon tips/m^2).

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Lamina Mass							
27	30 a	60 a	50 a	90 a	60 a	50 a	70 a
55	70 a	40 a	40 a	100 a	40 a	60 a	100 a
83	30 a	50 a	60 a	220 b	50 a	70 a	50 a
119	130 a	50 a	70 a	140 a	50 a	60 a	30 a
168	160 bc	50 a	80 ab	210 c	50 a	70 ab	60 a
b) Stolon Tip Density							
27	330 a	550 a	340 a	920 a	550 a	300 a	440 a
55	920 a	860 a	450 a	1760 a	860 a	310 a	830 a
83	510 a	710 a	1050 a	5790 b	710 a	790 a	40 a
85	620 a	690 a	500 a	1830 b	690 a	180 a	250 a
119	940 a	510 a	770 a	1520 a	510 a	340 a	240 a
168	1040 bc	320 a	290 a	1330 c	320 a	450 ab	250 a

Appendix Table 3e Leaf:Stem Ratio (L:S) a) Pregrazing and b) Post Grazing.

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Pregrazing							
27	1.34 a	1.14 a	1.08 a	1.02 a	1.14 a	1.15 a	0.99 a
55	1.28 b	0.79 a	0.42 a	0.75 a	0.79 a	0.65 a	0.76 a
83	1.28 c	1.01 bc	0.41 a	0.80 ab	1.01 bc	0.61 ab	0.55 a
119	1.26 a	1.38 a	1.09 a	1.05 a	1.38 a	1.50 a	1.46 a
168	1.83 a	2.07 a	1.83 a	1.80 a	2.07 a	1.77 a	2.18 a
b) Post Grazing							
28	0.34 a	0.41 ab	0.56 bc	0.69 c	0.41 ab	0.36 ab	0.39 ab
55	0.35 a	0.64 b	0.64 a	0.46 ab	0.64 b	0.38 a	0.29 a
85	0.44 b	0.38 b	0.13 a	0.41 b	0.38 b	0.19 a	0.15 a
120	0.64 a	0.50 a	0.54 a	0.44 a	0.50 a	0.49 a	0.44 a

Appendix Table 3f Percentage Ryegrass Reproductive Stubble in a)Total Ryegrass b) Green and c) Total Herbage Masses.

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Total Ryegrass							
27	24 a	32 a	32 a	29 a	32 a	32 a	38 a
55	22 a	31 a	61 b	33 a	31 a	43 ab	47 ab
83	12 a	28 ab	59 c	22 a	22 ab	49 c	45 bc
b) Green							
27	22 a	28 ab	29 ab	23 a	28 ab	27 ab	35 b
55	19 a	24 a	49 a	28 a	24 a	41 a	43 a
83	9 a	26 a	54 b	13 a	26 a	47 b	41 b
c) Total							
27	15 a	20 ab	19 a	16 a	20 ab	21 ab	26 b
55	14 a	17 a	36 a	18 a	17 a	29 a	33 a
83	6 a	17 a	43 c	9 a	17 a	35 bc	29 b

Appendix Table 3g Mean Lamina Mass per a) Vegetative and b) Reproductive Ryegrass Tiller, both i) Pregrazing and ii) Post-grazing, over the Treatment Period (mg/tiller).

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Vegetative							
i) Pregrazing							
27	7.5 a	9.2 ab	8.1 a	6.1 a	9.2 ab	12.6 bc	14.2 c
55	7.4 ab	8.7 ab	15.0 c	5.4 a	8.7 ab	12.5 bc	15.4 c
83	5.9 a	9.1 ab	13.6 bc	5.5 a	9.1 ab	15.3 c	16.8 c
ii) Post-grazing							
28	1.7 a	4.5 b	7.3 c	4.5 b	4.5 b	4.2 b	4.3 b
56	1.9 a	7.0 b	10.5 c	4.2 ab	7.0 b	6.8 b	7.1 b
b) Reproductive							
i) Pregrazing							
27	11.2 ab	18.7 bc	19.6 bc	8.3 a	18.7 bc	18.2 bc	25.8 c
55	14.1 bc	12.4 ab	12.7 ab	5.2 a	12.4 ab	12.2 ab	22.0 c
83	9.3 ab	15.4 b	9.7 ab	5.6 a	15.4 b	14.2 b	10.9 ab
ii) Post-grazing							
28	1.7 a	3.5 a	9.9 a	4.6 a	3.5 a	4.7 a	13.9 a
56	2.5 a	3.6 a	9.8 b	5.6 ab	3.6 a	4.2 a	8.0 ab

Appendix Table 3h Leaf Area Index (LAI) a) Pregrazing and b) Post grazing.

	Intensity			Frequency			
Day	H14	M14	L14	M7	M14	M21	M28
a) Pregrazing							
27	1.95 a	2.78 ab	2.60 ab	2.05 a	2.78 ab	2.85 ab	3.50 b
55	2.34abc	2.49 bc	2.14 ab	1.58 a	2.49 bc	2.42 bc	3.15 c
83	1.45 a	2.02 a	1.91 a	2.04 a	2.02 a	2.20 a	2.64 a
119	2.82 b	2.21 ab	1.47 a	2.19 ab	2.21 ab	2.01 a	1.77 a
b) Post grazing							
28	0.38 a	0.91 bc	1.78 d	1.24 c	0.91 bc	0.86 bc	0.67 b
56	0.28 a	1.36 b	1.51 b	0.99 b	1.36 b	1.04 b	1.22 b
85	0.27 a	0.38 a	0.54 a	0.33 a	0.38 a	0.29 a	0.40 a
120	0.74 a	0.58 a	0.45 a	0.55 a	0.58 a	0.49 a	0.49 a

Appendix 4 **Tables of herbage accumulations: Means and relevent statistics.**

Appendix
Table

4a Total herbage accumulation (kgDM/ha)

4b Green herbage accumulation (kgDM/ha)

4c Total Lamina accumulation (kgDM/ha)

4d White clover a) lamina and b) total herbage accumulation (kgDM/ha)

4e Other grasses a) lamina and b) total herbage accumulation (kgDM/ha)

4f Ryegrass a) vegetative and b) reproductive stubble accumulation (kgDM/ha)

4g Dead a) 'leaf' and b) 'stubble' accumulation (kgDM/ha)

4h Percentage a) ryegrass, b) white clover and c) other grasses in total lamina accumulation

Appendix Table 4a Total Herbage Accumulation (kgDM/ha).

	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
1	2390 a	2390 a	2130 a	1850 a	2390 a		2690 a
2	3420 a	2710 a	2650 a	2890 a	2710 a		2840 a
3	2760 a	2390 a	2950 a	3130 a	2390 a		3550 a
1-3	8580 a	7490 a	7740 a	7870 a	7490 a	7480 a	9080 a
4	3000 a	2130 a	1530 a	2510 a	2130 a	1790 a	2050 a
5	1900 a	1570 a	870 a	1720 a	1570 a	1660 a	1720 a
4-5	4900 a	3690 a	2400 a	4230 a	3690 a	3440 a	3770 a
Total	13490 a	11180 a	10130 a	12100 a	11180 a	10920 a	12850 a

Appendix Table 4b Green Herbage Accumulation (kgDM/ha).

	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
1	1830 a	1920 a	1580 a	1430 a	1920 a		2110 a
2	2890 a	2360 a	2690 a	2510 a	2360 a		2450 a
3	2220 a	1970 a	2280 a	2550 a	1970 a		2430 a
1-3	6950 a	6250 a	6540 a	6490 a	6250 a	6510 a	7000 a
4	2980 e	1880 cd	-250 a	2370 de	1880 cd	1170 bc	310 ab
5	1380 b	1190 b	520 a	1370 b	1190 b	1640 b	1230 b
4-5	4360 d	3070 cd	270 a	3730 cd	3070 cd	2810 bc	1540 ab
Total	11310 c	9320 ab	6810 a	10230 bc	9320abc	9320abc	8540 ab

Appendix Table 4c Total Lamina Accumulation (kgDM/ha).

	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
1	1380 a	1470 a	1170 a	1340 a	1470 a		1240 a
2	2010 c	1650 b	840 a	1760 bc	1680 b		1240 a
3	1560 b	1680 b	590 a	1660 b	1680 b		1220 b
1-3	4950 c	4800 bc	2600 a	4760 bc	4800 bc	3730 ab	3700 ab
4	1760 a	1360 a	1000 a	1360 a	1360 a	1270 a	1110 a
5	1170 b	1260 b	700 a	1330 b	1260 b	1380 b	1300 b
4-5	2930 b	2620 b	1700 a	2690 b	2620 b	2650 b	2420 b
Total	7880 d	7420 cd	4300 a	7440 cd	7420 cd	6380 bc	6110 b

Appendix Table 4d White Clover a) Lamina and b) Total Herbage Accumulation (kgDM/ha).

Period	Intensity			Frequency			
	H14	M14	L14	M7	M14	M21	M28
a) Lamina							
1	50 a	30 a	-10 a	100 a	30 a		50 a
2	100 ab	30 a	0 a	190 b	30 a	(150)	80 ab
3	30 a	40 a	60 a	370 b	40 a		20 a
4	80 a	-30 a	20 a	50 a	-30 a	20 a	-10 a
5	140 bc	30 a	50 ab	160 c	30 a	70 ab	50 ab
b) Total							
1	80 a	40 a	-60 a	180 a	40 a		80 a
2	160 ab	40 a	-20 a	320 b	40 a	(300)	50 a
3	0 a	80 a	50 a	860 b	80 a		300 a
4	310 a	40 a	170 a	190 a	40 a	110 a	60 a
5	320 c	-30 a	40 ab	270 bc	-30 a	140 abc	70 ab

Appendix Table 4e Other Grasses a) Lamina and b) Total Herbage Accumulation (kgDM/ha).

	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
a) Lamina							
1	80 a	110 a	10 a	10 a	110 a		40 a
2	110 a	180 a	140 a	60 a	180 a	(210)	80 a
3	90 a	-70 a	130 a	150 a	-70 a		-10 a
4	80 a	-30 a	20 a	50 a	-30 a	20 a	-10 a
5	-20 a	-10 a	10 a	10 a	-10 a	-10 a	-10 a
b) Total							
1	130 a	140 a	-20 a	160 a	140 a		90 a
2	190 a	390 a	580 a	-50 a	390 a	(340)	170 a
3	180 a	-320 a	260 a	590 a	-320 a		-50 a
4	150 a	-40 a	0 a	160 a	-40 a	0 a	-50 a
5	-30 a	-60 a	30 a	-70 a	-60 a	-80 a	-50 a

Appendix Table 4f Ryegrass a) Vegetative and b) Reproductive Stubble Accumulation (kgDM/ha).

	Intensity			Frequency			
Preiod	H14	M14	L14	M7	M14	M21	M28
a) Vegetative							
1	30 a	-210 a	-110 a	130 a	-210 a		-70 a
2	450 a	530 a	470 a	380 a	530 a		300 a
3	500 a	-200 a	530 a	1040 a	-200 a		640 a
1-3	980 a	120 a	900 a	1550 a	120 a	530 a	860 a
4	910 b	530 a	380 a	550 a	530 a	420 a	490 a
5	300 a	130 a	-30 a	120 a	130 a	280 a	190 a
4-5	1210 b	660 a	350 a	670 a	660 a	700 a	680 a
1-5	2190 a	780 a	1250 a	2230 a	780 a	1230 a	1550 a
b) Reproductive							
1	430 ab	660 bc	510 bc	-40 a	660 bc		950 c
2	430 a	330 a	1370 a	370 a	330 a		910 a
3	170 a	740 a	730 a	-150 a	740 a		580 a
1-3	1030 a	1740 a	2610 a	180 a	1740 a	2250 a	2440 a
4	310 c	-10 bc	-1640 a	450 c	-10 bc	-510 b	-1290 a
5	-100 a	-200 a	-140 a	-80 a	-200 a	-20 a	-260 a
4-5	210 bc	-210bc	-1780 a	370 c	-210 bc	-540 b	-1550 a
1-5	1240 a	1510 a	830 a	550 a	1530 a	1710 a	880 a

Appendix Table 4g Dead a) 'Leaf' and b) 'Stubble' accumulation (kgDM/ha).

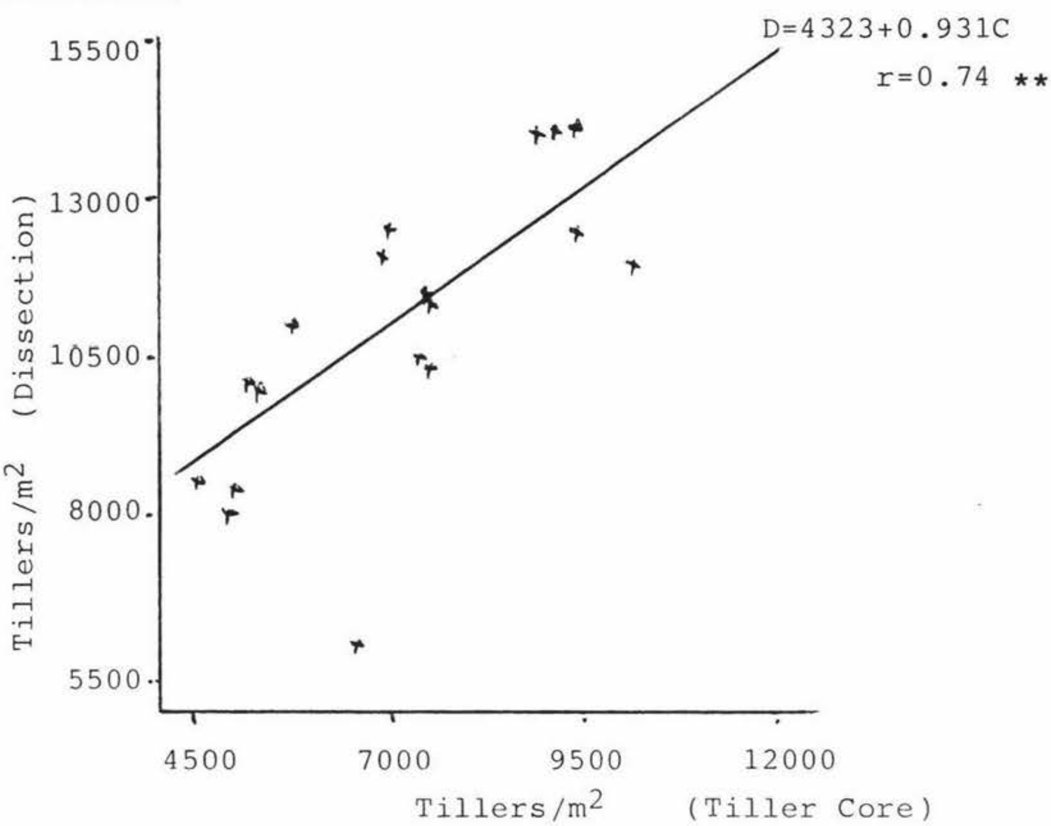
	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
a) 'Leaf'							
1	560 a	470 a	560 a	420 a	470 a		570 a
2	430 a	320 a	-90 a	230 a	320 a		180 a
3	160 a	-70 a	90 a	310 a	-70 a		300 a
1-3	1150 a	730 a	560 a	960 a	730 a	580 a	1050 a
4	200 a	140 a	90 a	140 a	140 a	30 a	660 a
5	560 a	440 a	750 a	470 a	440 a	380 a	570 a
4-5	760 a	580 a	840 a	610 a	580 a	410 a	1230 a
1-5	1910 bc	1300 ab	1400 ab	1580 ab	1300 ab	990 a	2280 c
b) 'Stubble'							
1	0 a	0 a	0 a	0 a	0 a		0 a
2	100 a	30 a	60 a	150 a	30 a		210 a
3	380 a	490 a	580 a	260 a	490 a		830 a
1-3	480 a	520 a	640 a	410 a	520 a	390 a	1030 a
4	-179 a	100 a	1700 c	0 a	100 a	580 ab	1080 bc
5	-40 a	-60 a	-410 a	-120 a	-60 a	-360 a	-90 a
4-5	-210 a	40 a	1290 a	-110 a	40 a	220 a	1000 a
1-5	270 a	560 a	1930 b	300 a	560 a	610 a	2030 b

Appendix Table 4h Percentage of a) Ryegrass, b) White Clover and c) Other Grasses in Total Lamina Accumulation

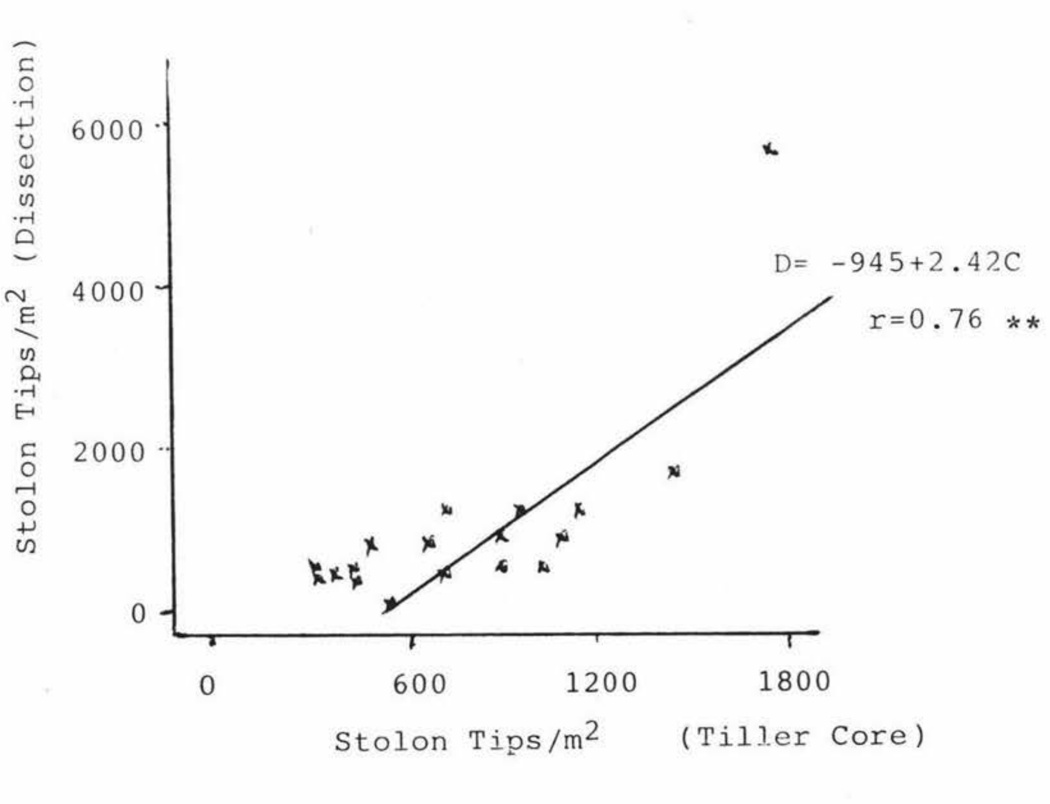
	Intensity			Frequency			
Period	H14	M14	L14	M7	M14	M21	M28
a) Ryegrass							
1	91 a	91 a	100 a	85 a	91 a		93 ab
2	90 a	86 a	81 a	86 a	86 a		87 a
3	92 b	97 b	90 ab	65 a	97 ab		98 b
4	89 a	99 a	92 a	86 a	99 a	94 a	98 a
5	89 a	100 b	91 ab	86 a	100 b	95 ab	98 b
b) White Clover							
1	3 a	3 a	-1 a	7 a	3 a		4 a
2	5 ab	2 a	0 a	11 b	2 a		6 ab
3	2 a	3 a	8 a	24 b	3 a		2 a
4	7 a	3 a	7 a	9 a	3 a	5 a	3 a
5	13 b	1 a	8 ab	13 b	1 a	5 ab	3 a
c) Other Grasses							
1	6 a	6 a	1 a	8 a	6 a		4 a
2	6 a	12 a	18 a	3 a	12 a		7 a
3	6 a	-1 a	1 a	11 a	-1 a		0 a
4	5 a	-2 a	1 a	4 a	2 a	1 a	-1 a
5	-2 a	-1 a	1 a	1 a	-1 a	-1 a	-1 a

Appendix 5 Comparison of a) Ryegrass, b) Other Grasses Tiller Density and c) White Clover Stolon Tip Density derived from Dissection Samples or Tiller Cores.

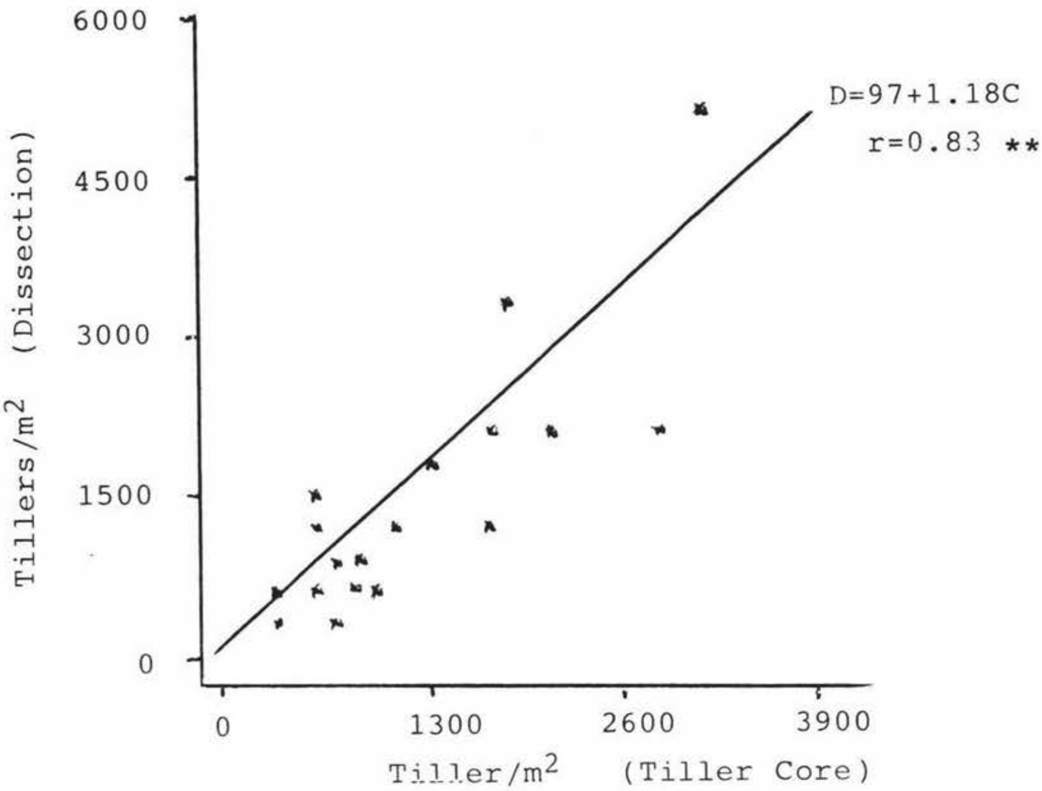
a) Ryegrass



b) White Clover



c) Other Grasses



<u>Appendix 6</u> **Comparison of Herbage Accumulation (kgDM/ha/day) from Small Cages using the Trim Technique and from the Grazing Trial.**

Month	A.S.D* Small Cages	Grazing Trial Total	Grazing Trial Green	Grazing Trial Lamina
September	39.2			
October	62.9	82	63	47 (42-53)
November	61.0	104	92	52 (30-72)
December	65.3	106	82	49 (20-59)
Januaury	32.9	64 (45-88)	41 (-7-88)	39 (29-52)
Februaury	17.6	33 (18-40)	25 (11-34)	25 (15-29)
March	35.1	3	NA	29
April	40.2	35	NA	NA
May	11.9	1	NA	18
June	23.9			

* Mean of two metal milk crate cages; cutting and processing were done by Jim McCrone, Advisory Services Division, M.A.F.

Appendix 7: Estimation of Herbage Mass using the Pasture Probe and Sward Height.

1. Introduction

Reasonably accurate estimation of herbage mass is essential for control over animal feed intakes (Milligan and Smith 1984) and understanding and communication of grazing management opportunities. Two objective measurement techniques for estimating herbage mass, a single probe capacitance meter (Design Electronics Pasture Probe) and sward height were compared in this study.

2. Methods

Measurement of sward height (SH) has been described in section 3.3.4. It should be noted that the technique gave estimates of total sward surface height (including live and dead stem and seedhead) rather than mean lamina height (see Webby and Pengally 1986).

Before and after each grazing 50 pasture probe readings (CMR) were taken on each plot. These were averaged and corrected for the air reading (i.e. CMR= air reading - pasture reading). Note that CMR was not measured on the three quadrats cut for herbage mass estimation.

SH and CMR were regressed with quadrat cuts of total, green and lamina masses (both in linear and quadratic forms), and with each other. Data was regressed as a whole, split into time intervals (days 0-28, 34-56, 62-85 and 119-168) or split into two groups of treatments H14, M7 and M14, and treatments L14, M21 and M28.

3. Results and Discussion

The linear and quadratic regressions of SH and CMR with total, green and lamina masses were significant throughout the trial (Appendix Table 7.1). However, in only a few cases was the quadratic term significant (Appendix Table 7.1) and therefore, for simplicity, presentation and discussion of results will be limited to linear regressions.

Similar results have been obtained with the pasture probe by others. For example, Vickery et al (1980) found little difference in the proportion of variance accounted for by linear or quadratic regressions. Crosbie et al (in press) found that quadratic or curvilinear refinements were only occasionally warranted. Both quadratic (e.g. Webby and Pengally 1986) and linear (e.g. Piggot 1986) regressions have been used to describe the relationship between SH and herbage mass.

It is also apparent that within each time period there is little difference between the ability of CMR or SH to predict herbage mass (Appendix Table 7.1) especially as both these measurements were very highly correlated with each other (Appendix Figure 7.1, Appendix Table 7.2).

Appendix Table 7.1 Linear and Quadratic Regressions* of a) Total, b) Green and c) Lamina Herbage Mass with CMR and SH.

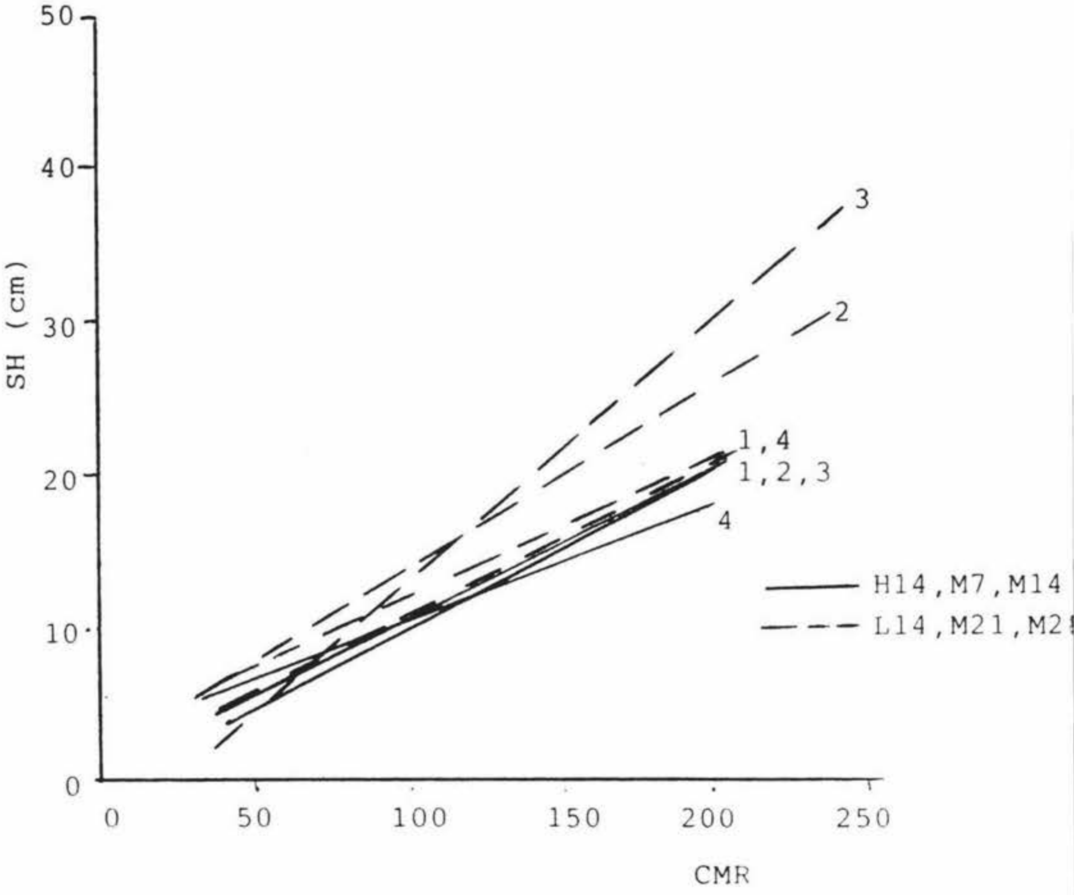
Dependent Variable	Period	All Treatments Linear	All Treatments Quad	R^2 H14,M7,M14 Linear	H14,M7,M14 Quad	L14,M21,M28 Linear	L14,M21,M28 Quad
a) Total							
CMR	0-28	74	74	68	67	72	71
	34-56	75	74	60	60	56	56
	62-85	80	80	67	66	65	65
	119	67	67	70	69	66	66
	0-168	66	66	57	56	55	54
SH	0-28	73	75	67	70	70	74
	34-56	78	81	54	62	66	66
	62-85	76	79	68	75	56	56
	119	70	71	59	67	69	71
	0-168	64	67	50	56	52	55
b) Green							
CMR	0-28	80	80	72	71	79	80
	34-56	79	79	69	69	61	61
	62-85	86	86	69	69	79	79
	119	45	39	71	70	51	51
	0-168	73	73	61	61	69	69
SH	0-28	78	78	69	69	79	80
	34-56	83	85	64	68	73	75
	62-85	81	83	64	75	70	70
	119	27	45	64	75	70	70
	0-168	73	74	54	58	75	75

* $P < 0.01$ unless otherwise specified

Appendix Table 7.1 (continued)

Dependent Variable	Period	R^2 All Treatments Linear	All Treatments Quad	H14,M7,M14 Linear	H14,M7,M14 Quad	L14,M21,M28 Linear	L14,M21,M28 Quad
c) Lamina							
CMR	0-28	85	85	82	82	84	84
	34-56	71	70	76	76	75	75
	62-85	54	54	78	78	68	68
	119	57	56	85	85	58	57
	0-168	56	56	65	65	58	57
SH	0-28	84	84	82	81	83	83
	34-56	59	63	71	73	71	72
	62-85	41	48	70	74	56	55
	119	28	46	64	71	24	37
	0-168	36	47	53	55	33	40

Appendix Figure 7.1 Relationship between SH and CMR over Four Measurement Periods*.



* In this Figure and Appendix Figures 7.2-7.5 the four periods are indicated by:

1 days 0-28

2 days 34-56

3 days 62-85

4 days 119-168

Appendix Table 7.2 Linear Regressions of SH with CMR.

Dep. Var.	Period	Regression Coefficients a	(se)	b	(se)	Signif. a	b	S.E.	R^2	
SH (123*)	0-28	0.20	(.39)	.105	(.004)	ns	***	1.4	.92	***
	34-56	0.53	(.42)	.103	(.004)	ns	***	1.4	.93	***
	62-85	-0.46	(.47)	.109	(.005)	ns	***	1.6	.87	***
	119	2.62	(.95)	.076	(.008)	**	***	2.2	.73	***
	0-168	0.46	(.26)	.100	(.002)	ns	***	1.7	.88	***
(456)	0-28	-0.11	(.61)	.107	(.005)	ns	***	1.7	.95	***
	34-56	1.80	(2.62)	.125	(.013)	ns	***	4.6	.76	***
	62-85	-2.79	(1.64)	.159	(.008)	ns	***	3.9	.90	***
	119	3.59	(1.20)	.079	(.008)	**	***	2.8	.74	***
	0-168	-.169	(.95)	.135	(.005)	ns	***	4.7	.81	***

* 123 are treatments H14, M14 and M7; 456 are treatments L14, M21 and M28.

The following sections will consider separately the regressions of SH and CMR with total (3.1), green (3.2) and lamina (3.3) herbage masses.

3.1 Total Herbage Mass

The regressions derived in this study (Appendix Table 7.3a, Appendix Figure 7.2) of SH and CMR with total herbage mass compare well with those of other studies especially within individual periods rather than the overall regressions. For example, the range of R2 found in other studies for CMR are 85 and Large 1983), 83-87 (Crosbie et al, in press), 61 (Piggot 1986) and 73-87 and for SH are 82 (Webby and Pengally 1986). It is also clear from these studies and Appendix Table 7.2 that there is little difference in the prediction of total herbage mass by either SH or CMR.

Both SH and CMR regressions with total herbage mass varied between periods. Similar variation has been found by Richardson (1984) and Michell and Large (1983).

3.2 Green Herbage Mass

Regressions of SH and CMR with green herbage mass were generally better than with total herbage mass (Appendix Table 7.1b). Richardson (1984) and Sheath et al (1985) gained similar results with CMR. Richardson (1984) suggested that poor electrical conductivity of the dead herbage and inconsistence of surface area measurement were the most likely

Appendix Table 7.3 Linear Regressions of a) Total b) Green and c) Lamina Herbage Mass with CMR and SH.

Dep. Var.	Period	Regression Coefficients a (se)		b (se)		Signif. a	b	S.E.	R^2	
a) Total										
CMR (123*)	0-28	1024	(108)	12.7	(1.0)	***	***	384	.67	***
	34-56	1314	(149)	12.6	(1.3)	***	***	491	.60	***
	62-85	1042	(157)	20.0	(1.8)	***	***	540	.67	***
	119	1305	(245)	18.2	(2.0)	***	***	570	.70	***
	0-168	1171	(90)	15.0	(0.8)	***	***	594	.57	***
(456)	0-28	1431	(181)	12.1	(1.2)	***	***	516	.72	***
	34-56	2299	(354)	10.8	(1.7)	***	***	626	.56	***
	62-85	1911	(377)	16.4	(1.9)	***	***	896	.65	***
	119	2113	(331)	17.9	(2.2)	***	***	784	.66	***
	0-168	1857	(191)	14.5	(1.1)	***	***	943	.55	***
SH (123)	0-28	1048	(105)	116.3	(9.3)	***	***	380	.67	***
	34-56	1370	(162)	112.0	(12.9)	***	***	528	.54	***
	62-85	1217	(139)	173.5	(14.9)	***	***	529	.68	***
	119	1230	(314)	190.4	(26.5)	***	***	661	.59	***
	0-168	1277	(95)	132.5	(8.5)	***	***	636	.50	***
(456)	0-28	1512	(182)	108	(10.8)	***	***	535	.70	***
	34-56	2274	(296)	81.8	(10.5)	***	***	554	.66	***
	62-85	2509	(373)	90.9	(13.0)	***	***	1005	.56	***
	119	1677	(352)	199.9	(22.4)	***	***	742	.69	***
	0-168	2313	(170)	94.1	(7.4)	***	***	973	.52	***

* 123 are treatments H14, M14 and M7; 456 are treatments L14, M21 and M28.

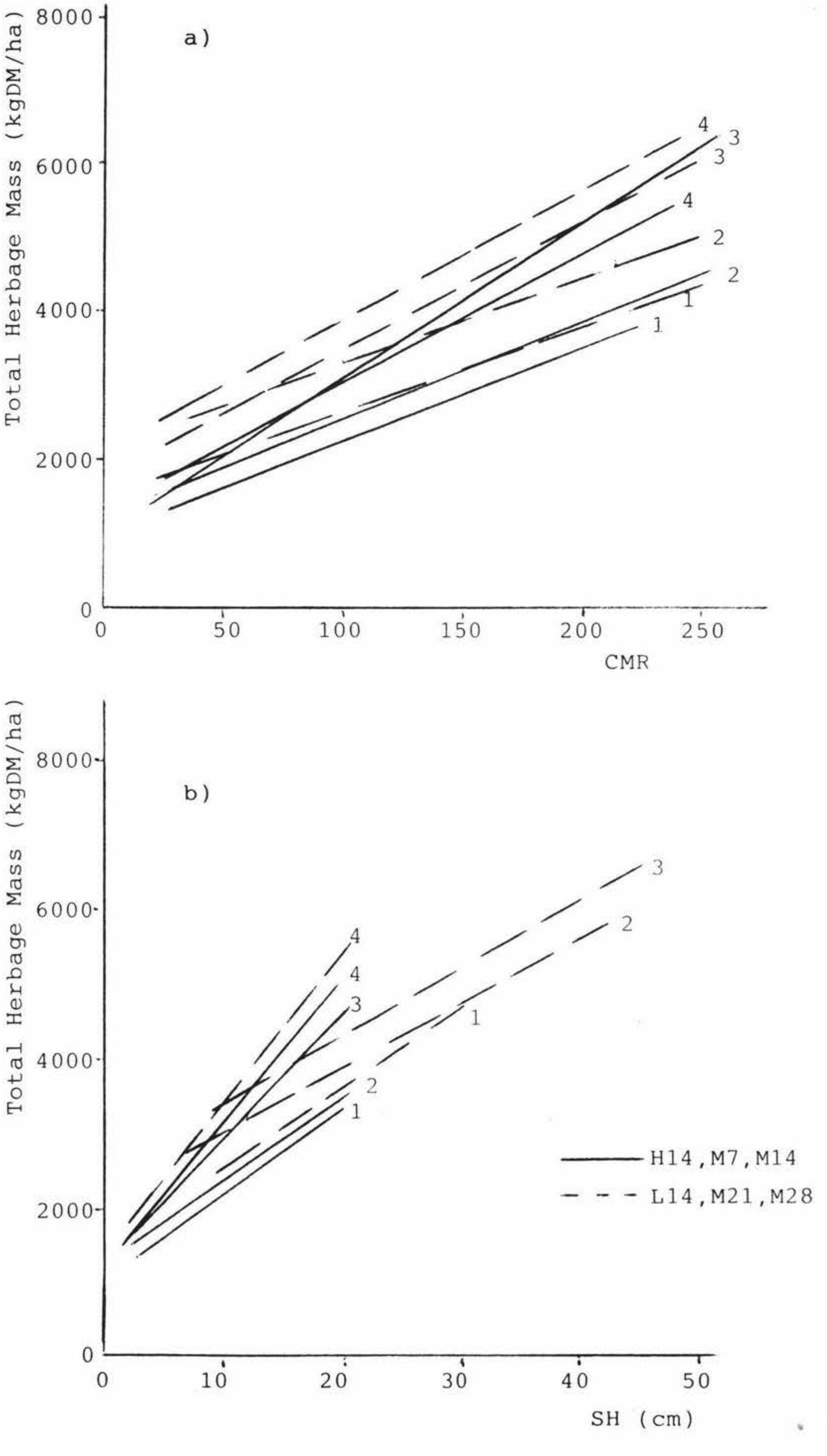
Appendix Table 7.3 (continued)

Dep. Var.	Period	Regression Coefficients a	(se)	b	(se)	Signif. a	b	S.E.	R^2	
c) Lamina										
CMR (123)	0-28	-35	(40)	6.9	(0.4)	ns	***	141	.82	***
	34-56	48	(51)	6.9	(0.4)	ns	***	170	.76	***
	62-85	-4	(52)	8.8	(0.6)	ns	***	178	.78	***
	119	-115	(107)	12.4	(0.9)	ns	***	248	.85	***
	0-168	-26	(41)	8.2	(0.4)	ns	***	271	.65	***
(456)	0-28	-2	(65)	6.3	(0.4)	ns	***	184	.84	***
	34-56	-202	(128)	6.0	(0.6)	ns	***	227	.75	***
	62-85	-27	(137)	6.4	(0.7)	ns	***	326	.68	***
	119	98	(157)	7.2	(1.0)	ns	***	372	,58	***
	0-168	50	(69)	5.6	(0.4)	ns	***	341	.58	***
SH (123)	0-28	-19	(39)	63.3	(3.5)	ns	***	142	.82	***
	34-56	63	(57)	57.0	(4.6)	ns	***	186	.71	***
	62-85	114	(55)	71.7	(5.9)	*	***	210	.70	***
	119	-85	(183)	122.6	(15.4)	ns	***	385	.64	***
	0-168	65	(47)	69.3	(4.2)	ns	***	316	.52	***
(456)	0-28	35	(66)	56.8	(3.9)	ns	***	192	.83	***
	34-56	-102	(131)	40.6	(4.6)	ns	***	245	.71	***
	62-85	-21	(142)	34.6	(4.9)	ns	***	382	.56	***
	119	335	(236)	52.4	(15.1)	ns	**	499	.24	***
	0-168	383	(74)	28.3	(3.2)	***	***	427	.33	***

Appendix Table 7.3 (continued)

Dep. Var.	Period	Regression Coefficients a	(se)	b	(se)	Signif. a	b	S.E.	R^2	
b) Green										
CMR (123)	0-28	474	(79)	10.2	(0.7)	***	***	275	.72	***
	34-56	623	(99)	10.2	(0.8)	***	***	325	.69	***
	62-85	398	(115)	15.6	(1.3)	***	***	398	.69	***
	119	626	(201)	15.3	(1.7)	***	***	468	.70	***
	0-168	515	(67)	12.3	(0.6)	***	***	440	.61	***
(456)	0-28	766	(114)	9.6	(0.7)	***	***	324	.80	***
	34-56	1089	(302)	10.2	(1.4)	**	***	533	.61	***
	62-85	544	(247)	15.1	(1.3)	*	***	587	.78	***
	119	769	(221)	8.9	(1.5)	**	***	524	.51	***
	0-168	522	(122)	12.6	(0.7)	***	***	605	.69	***
SH (123)	0-28	514	(79)	91.2	(7.0)	***	***	287	.69	***
	34-56	655	(108)	92.0	(8.7)	***	***	353	.64	***
	62-85	563	(108)	131.7	(11.7)	***	***	413	.67	***
	119	501	(245)	165.2	(20.6)	*	***	515	.64	***
	0-168	609	(72)	107.8	(6.4)	***	***	481	.53	***
(456)	0-28	819	(113)	86.5	(6.7)	***	***	332	.79	***
	34-56	1046	(239)	77.5	(8.5)	***	***	446	.73	***
	62-85	1056	(257)	85.5	(8.8)	***	***	693	.70	***
	119	940	(302)	72.9	(19.2)	**	***	637	.28	***
	0-168	834	(95)	87.4	(4.2)	***	***	548	.75	***

Appendix Figure 7.2 Relationship between a) CMR and b) SH and Total Herbage Mass.



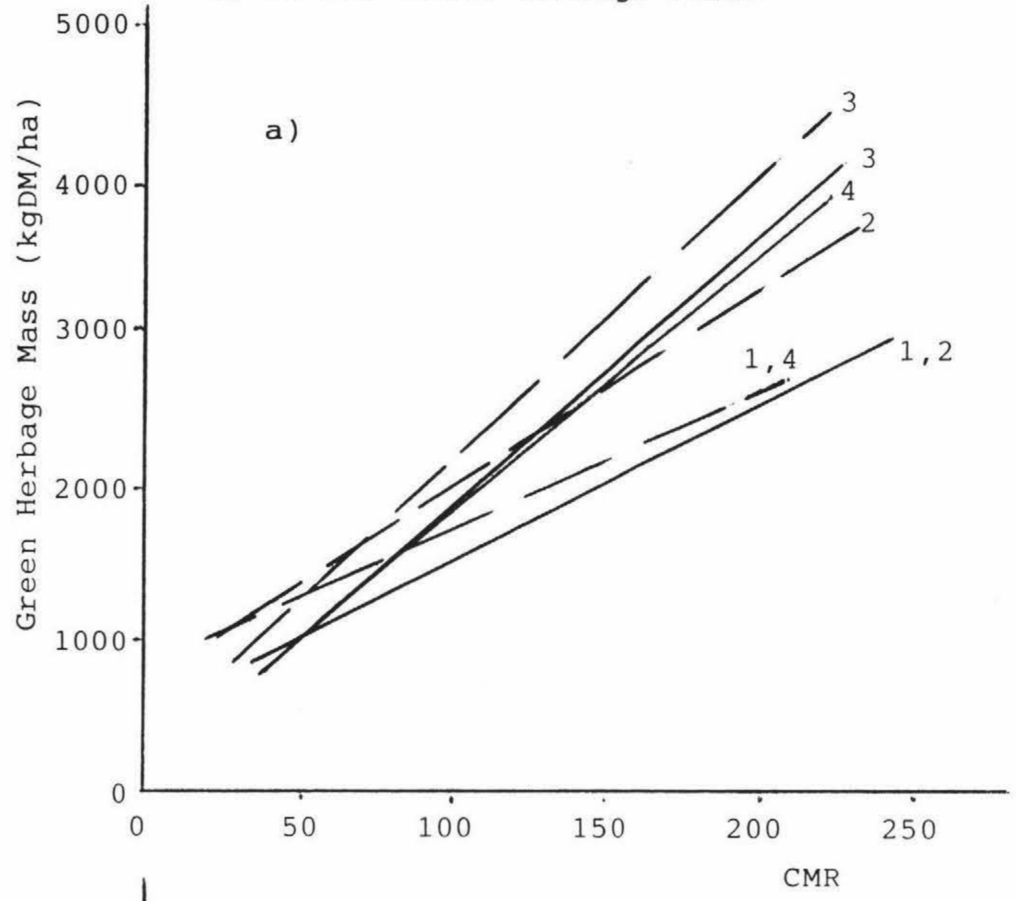
reason. During the treatment period SH measured green herbage height and variation in dead herbage content within the canopy (Text Table 4.1) most likely caused greater variability of regressions with total herbage mass.

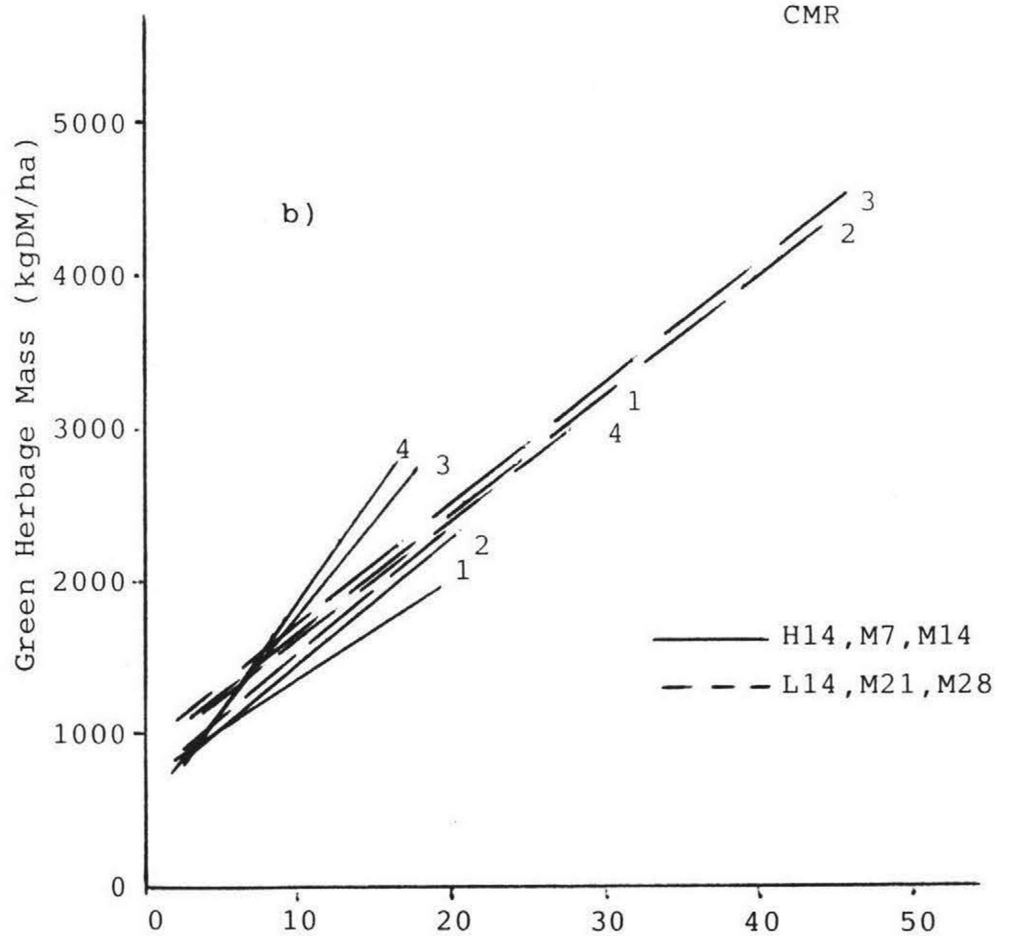
As with total herbage mass the regressions of CMR with green herbage mass varied between measurement periods (Appendix Figure 7.3a). There are two possible reasons for these changes. With treatments L14, M21 and M28 changes are probably due to the inability of the probe to measure herbage mass that is above the height of the sensing plate. This plate rises 20 cm above the soil surface and therefore any herbage that is above that height will not be measured and a greater herbage height for a given CMR will result. In the case of these treatments the herbage mass was up to 30 cm above the sensing plate (see Text Figure 4.15).

This explanation is supported by the relationship between the SH of treatments L14, M21 and M28 and green herbage mass. This relationship was stable over the whole study period (Appendix Figure 7.3b) and it is clear that the relationship of SH and CMR changed for these treatments only during days 34-85 through which SH increased above 20 cm (Appendix Figure 7.1). Similar results have been found by Butler (unpubl. data).

During the post-treatment period (days 119-168) the coefficients of variation in both CMR and SH regressions were reduced. Lower values were probably related to the increased proportion of dead herbage in the swards (see previous comment with regard to CMR and Text Figure

Appendix Figure 7.3 Relationship between a) CMR and b) SH and Green Herbage Mass.





4.7). Greater reduction with SH was due to the measurement technique because the height of reproductive stem and seedhead was measured. In that case total herbage mass regressions were more accurate (Appendix Table 7.1) and measurement of green leaf height alone would probably have increased the accuracy of the latter.

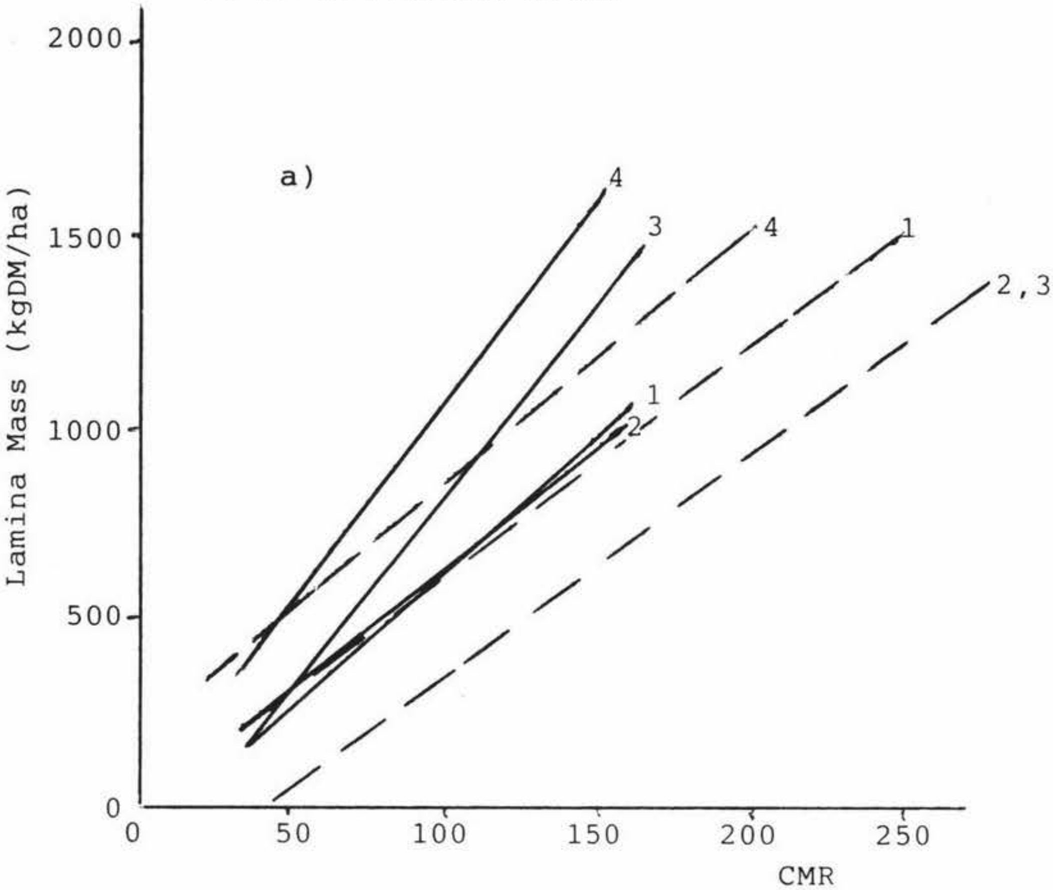
3.3 Lamina Mass

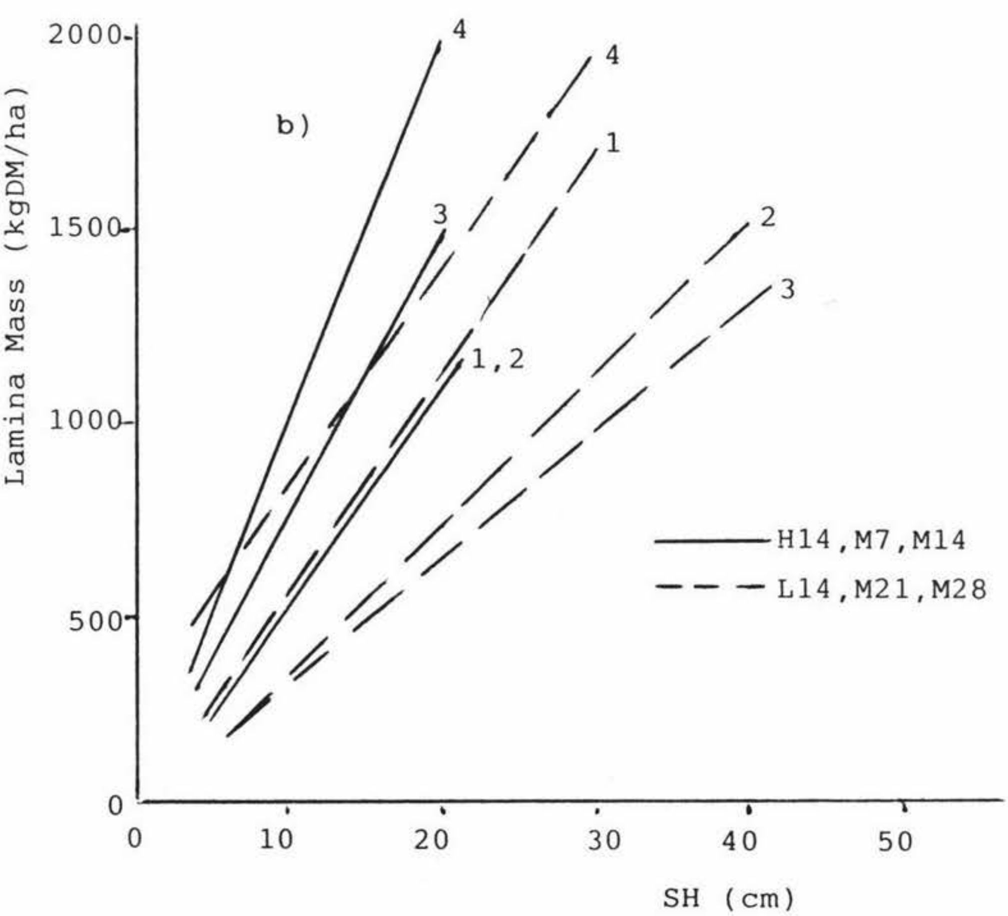
The relationship of both CMR and SH with lamina mass were generally better than with green or total herbage mass (Appendix Table 7.1). The main exception was in treatments L14, M21 and M28 on days 62-168 and the reasons for this have been discussed above (section 3.2).

However there was large variation in these regressions both between treatment groups and between measurement periods (Appendix Figure 7.4).

Differences in regressions between groups were a result of differences in the proportion of lamina in green or total herbage mass as multiple regressions across the groups of SH or CMR and Leaf:Stem ratio or Leaf:Non-leaf ratio accounted for a very high proportion of the variation in lamina mass (Appendix Table 7.4, Appendix Figure 7.5). These indicate that both measurement techniques cannot distinguish between leaf lamina and non lamina green components. However, if leaf height alone was measured (see Webby and Pengally 1986) then regressions of SH and lamina mass may have been very high. Subsequent observations by the author support this suggestion.

Appendix Figure 7.4 Relationship between a) CMR and b) SH and Lamina Mass.





Appendix Table 7.4 Multiple Linear Regressions of Lamina Mass with a) CMR and L:S*, b) CMR and L:Non-L, c) SH and L:S and d) SH and L:Non-L.

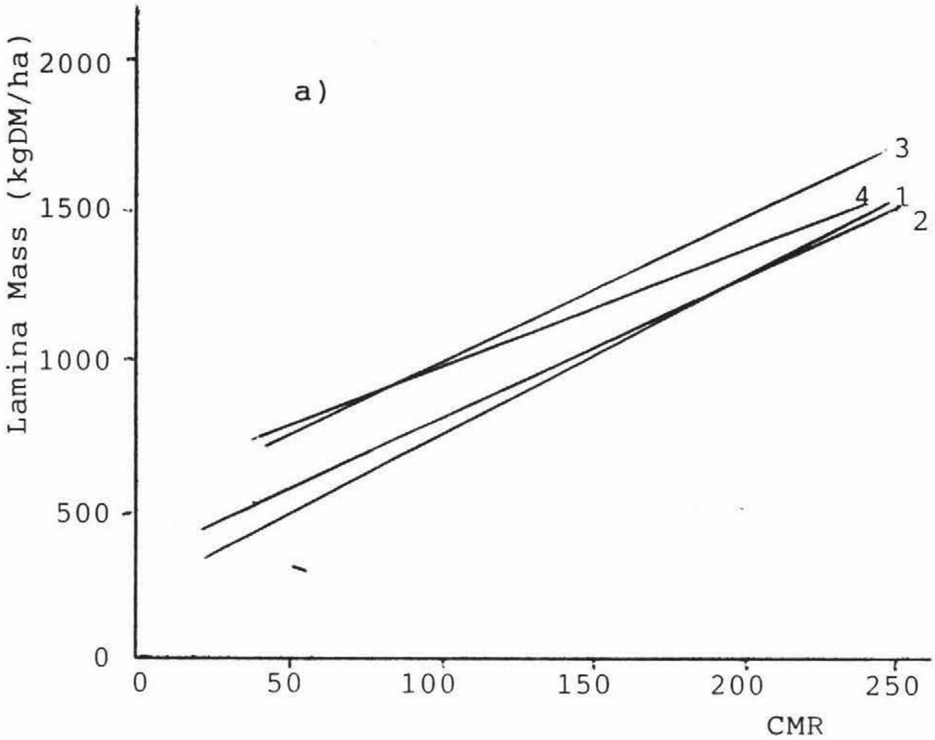
Period	Regression Coefficients						Significance			S.E.	R^2
	a	(se)	b	(se)	c	(se)	a	b	c		
a) CMR and L:S											
0-28	-131	(31)	5.2	(0.3)	370	(47)	***	***	***	130	.90 ***
34-56	-134	(40)	4.4	(0.2)	531	(47)	**	***	***	142	.88 ***
62-85	-242	(53)	4.8	(0.3)	745	(61)	***	***	***	204	.81 ***
119	70	(97)	4.0	(1.0)	501	(85)	ns	***	***	329	.71 ***
0-168	-131	(26)	4.4	(0.2)	559	(24)	***	***	***	212	.82 ***
b) CMR and L:Non-L											
0-28	-145	(26)	4.7	(0.2)	899	(79)	***	***	***	110	.92 ***
34-56	-107	(37)	4.0	(0.2)	1081	(90)	**	***	***	137	.88 ***
62-85	-103	(47)	4.2	(0.3)	1541	(116)	***	***	***	193	.83 ***
119	-63	(67)	5.8	(0.5)	1075	(86)	ns	***	***	224	.86 ***
0-168	-146	(24)	4.3	(0.2)	1253	(49)	***	***	***	201	.83 ***

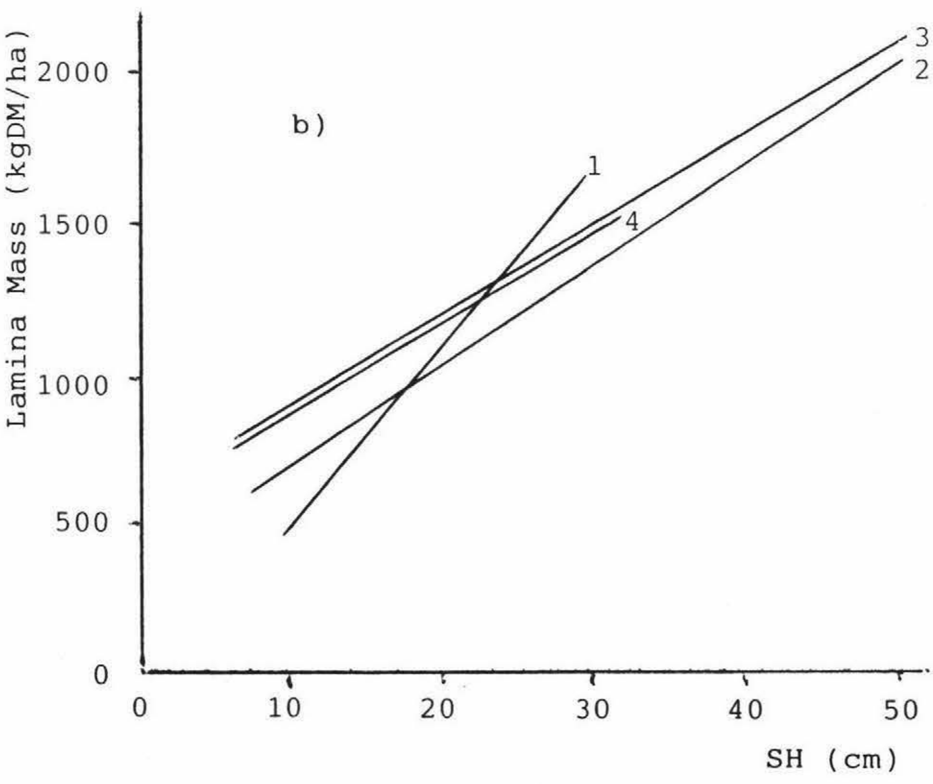
* See Text for definitions of L:S and L:Non-L, equations are for all treatments.

Appendix Table 7.4 (continued)

Period	Regression Coefficients						Significance			S.E.	R^2	
	a	(se)	b	(se)	c	(se)	a	b	c			
c) SH and L:S												
0-28	-104	(33)	47.3	(2.6)	353	(52)	**	***	***	138	.88	***
34-56	-105	(42)	29.6	(1.6)	654	(49)	*	***	***	151	.86	***
62-85	-167	(57)	28.3	(1.7)	862	(69)	**	***	***	229	.76	***
119	51	(114)	25.9	(8.7)	651	(69)	ns	**	***	344	.68	***
0-168	-108	(27)	29.3	(1.3)	699	(25)	***	***	***	226	.79	***
d) SH and L:Non-L												
0-28	-129	(27)	42.2	(2.3)	900	(84)	***	***	***	115	.92	***
34-56	-76	(38)	26.3	(1.5)	1302	(90)	*	***	***	144	.87	***
62-85	-126	(50)	24.4	(1.7)	1761	(126)	*	***	***	212	.80	***
119	-102	(93)	50.4	(6.2)	1327	(97)	ns	***	***	272	.80	***
0-168	-97	(27)	27.0	(1.3)	1509	(53)	***	***	***	226	.79	***

Appendix Figure 7.5 Relationship between a) CMR and b) SH and Lamina Mass assuming Leaf:Stem ratio equals 1.





4 Conclusions

It was argued in Text Section 5.7 that animal performance is better related to lamina mass than to green and especially total herbage masses over the late spring and summer. The results of this study are encouraging in that it may be possible to use CMR or SH to quickly estimate lamina mass at a level of accuracy that is acceptable for practical application. However further research is required especially with respect to estimation of lamina in green herbage mass before confidence can be placed in their use.

The seasonal variability of the pasture probe may be reduced by extending the length of sensing plate and it may also be possible to alter probe electronics (e.g. signal frequency) to make it less sensitive to non-lamina herbage.

Appendix 8

Autumn growth characteristics of ryegrass/white clover pastures following differential spring grazing management. (Follow-up work to B. Butler's M.AgSc trial).

M.A. Richardson

Introduction

Changes in sward characteristics (stubble, dead material accumulation, leaf area and tiller densities) produced by spring grazing treatments are likely to result in different growth characteristics over summer and autumn. These changes have been recorded by Barry during the post treatment period which extended to early March.

It is anticipated that residual effects may last further into autumn and could be measured with minimal resource requirements. I have agreed to undertake these measurements with Barry Butler

Objectives

i) To monitor pasture growth rates and sward characteristics under a common autumn grazing management.

ii) To assess any residual spring treatment effects, and in particular:

- the extent to which tiller densities restrict pasture growth rates in relatively open autumn sheep pastures.

- the time it takes for differences to disappear under common grazing management.

Methods

The following measurements are to be made both before and after grazing -

- Total DM assessment using pasture probe
- Pasture height
- Composition. A cut sample will be dissected into grass leaf/stem/clover/weeds/dead
- Tiller densities (pre-grazing samples taken only)

Timetable

1)	Early March:	Post grazing only	
	4 weeks		
2)	Early April:	Pre/post grazing *	Massey stock required for grazing
	4-5 weeks		
3)	Mid May:	Pre/post grazing *	
	5-6 weeks		
4)	Late June	Pre grazing only	

NB The pasture regrowth from (3) will be monitored over a 5-6 week period. Grazing could occur at any time after measurements have been taken as further work is not envisaged. (However, if any significant differences are still apparent by this time we may consider continuing the work).

Autumn growth characteristics of ryegrass/white clover pastures following differential spring grazing management

SUMMARY OF RESULTS

M.A. Richardson
C.C. Bell

A large amount of variation occurred in nearly all measurements undertaken on B.Butler's trial area. Few treatment differences were apparent. In summary -

i) Pasture Growth Rates

No significant differences between treatments

	(Period 1) (9/3 -9/4 13/3-13/4)	(Period 2) (9/4-27/4 13/4-27/4)	(Period 3) (2/5-20/6 9/5-20/6)
Mean (kg DM/ha/day)	3	35	1

ii) Total Herbage Accumulation

Treatment 3 (14 day, medium) accumulated significantly less herbage over the total trial period.

iii) Herbage Composition

No significant differences between treatments.

iv) Tiller Densities

No significant differences between treatments or dates

		Growing points/m^2
Mean Densities -	Grass	9,900
	Clover	1,190
	Weeds	430
		11,520

v) Height Measurements

No significant differences between treatments.

Correlations between height and DM (as measured by the probe) were variable.

Appendix 9 Publications resulting from the study

a) Butler B.M. (1984) The spring grazing compromise N.Z. J. Agric 149(5):29

b) Butler B.M., Chu A.C.P., Matthews P.N.P. and Korte C.J. (1986) Effects of spring grazing management on herbage mass and sward characteristics in a ryegrass white clover pasture Proc. XV Int. Grassld. Cong: in press

The spring grazing compromise

Barry Butler, an animal husbandry advisor with MAF in Palmerston North, offers some food for thought on how to decide on grazing policies.

Just what is "spring pasture control"? Pasture control can be defined as maintenance of pasture leaf growth, tiller numbers and species composition, and minimizing pasture structure deterioration so that maximum immediate and subsequent animal production can be attained.

This can be achieved by grazing or topping (see *NZ Journal of Agriculture* of September 1984). If this cannot be done, then areas of the farm should be shut up for hay or, preferably, silage.

This article specifically looks at the differences in pastures whose condition would be described as "controlled" or "uncontrolled". It outlines the likely grazing management that would create these differences. Particular reference is made to information gathered in a trial at Massey University by the author.

One objective of spring and early summer grazing management is to maximize the weights of ewes and lambs at weaning. Another is to maintain pastures in a condition that will ensure the best possible production over summer and autumn.

Pasture grazing and cutting trials clearly show that lax grazing is detrimental and hard grazing beneficial to spring and, in dry summers, summer and autumn pasture growth rates.

Other grazing trials in New Zealand have shown that for lactating ewes and lambs, residual dry matter levels of at least 1200-1400 kg of green dry matter per hectare are required to achieve high weaning weights. On the other hand, hard grazing (to2-3 cm or 600 kg of green DM per hectare) results in poor ewe and lamb growth. These grazing trials have, however, been done in such a way that pastures grazed to high residual dry matter levels have not been allowed to deteriorate. Therefore, the poor lamb growth that has often been recorded on laxly grazed pasture in farm situations did not eventuate.

Hard grazing has often been advocated in spring because, although current animal growth will be reduced, future production will be ensured. There is an apparent compromise between grazing for maximum animal growth on one hand and pasture control on the other.

The question that needs to be asked, however, is: "How intense does grazing have to be to maintain pastures of high quality and at the same time sustain high ewe and lamb growth throughout the spring and early summer?"

Before we can answer that question, the factors that are most important in determining whether a pasture is controlled or not, must be examined.

With high pasture growth rates, and magnified by the reproductive development of grasses, the pasture changes typifying lack of control are far more rapid in spring than in other seasons. Lack of control is associated with decreased net production of leaf during spring, deterioration of pasture structure and species composition (especially clover content) and low tiller numbers. See figure 1.

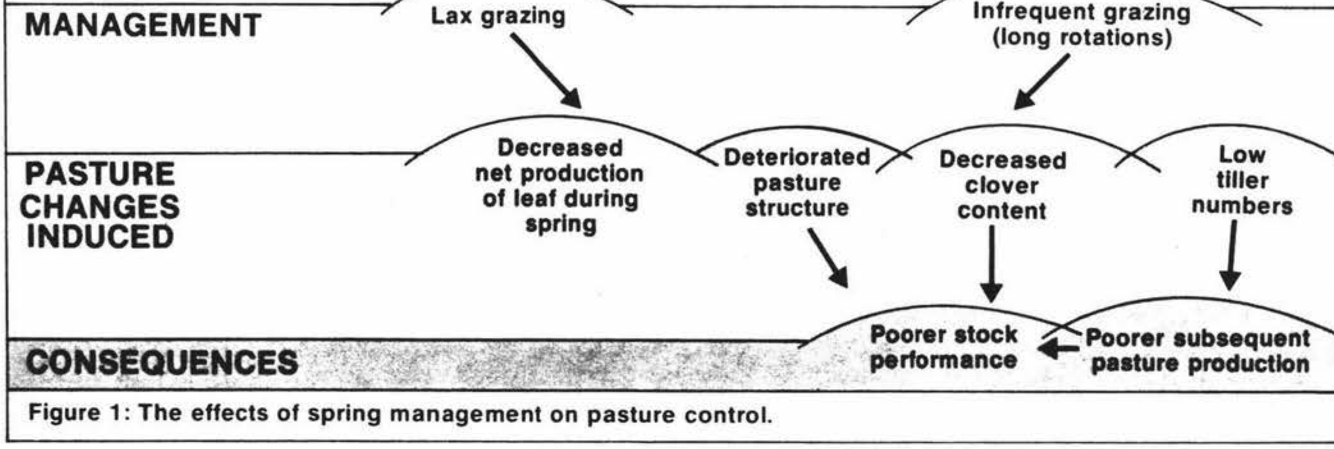
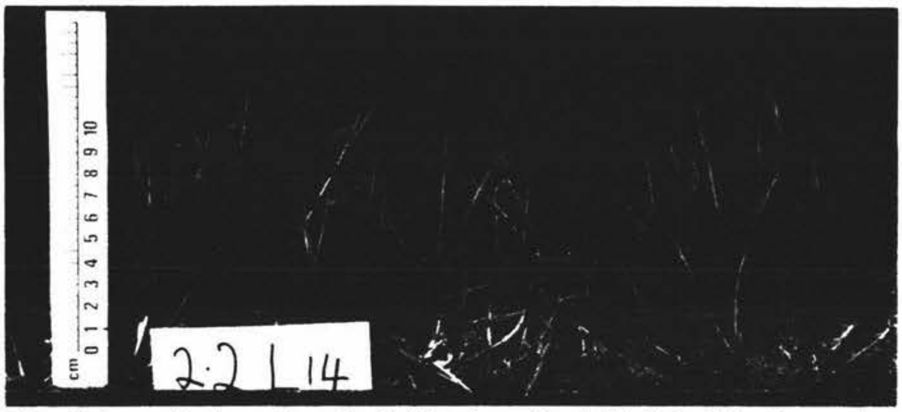


Figure 1: The effects of spring management on pasture control.



This photograph shows the effect of hard grazing (initially to 2-3cm) on spring pastures. The photograph was taken in mid-December after three months grazing.

Leaf production

In most situations, unless it is very hard grazed, leaf material forms the bulk of the sheep's diet. Leaf material, especially clover, is of much higher quality than the other components of the diet (stem and dead material). Therefore any reduction in the amount of leaf produced by the pasture will mean reduced animal growth and/or stocking rates, thereby reducing weaning weights and production per hectare.

The author's results show that net leaf production can be reduced by up to 40 percent by lax grazing and 26 percent by rotational grazing where pasture was long before grazing. The clover content of the uncontrolled pasture was also reduced.

Pasture structure

The accessibility of the leaf material in the pasture is also very important. Sheep will tend to try and maintain the quality of their diet (that is, they'll go for leaf content) even when this means reduced intakes. Pastures that are out of control have a high number of large seedheads and an accumulation of dead matter. The proportion of leaf in the pasture is low and becomes intermingled with the poorer quality material. This inhibits the ability of sheep to maintain high intakes of leaf and reduces performance.

Note that pasture control does not just mean the removal of seedhead, as sheep can graze pastures with quite high numbers of seedheads without performance being significantly affected.

Subsequent pasture production

Pastures that become long and rank also have low numbers of tillers (pasture growth sites). Earlier trials have shown that this may cause a serious depression in subsequent pasture growth rates especially when the summer is dry. Under these conditions, summer and especially autumn pasture growth can be reduced severely. If the summer is moist, then once the pasture has been "cleaned up" by cutting or hard grazing (preferably with low priority stock), then it will quickly recover.

Grazing for control

In the author's trial on a ryegrass white clover pasture, control was achieved very well by grazing stock to 6-8 cm (1400 kg green DM per hectare). Hard grazing (to 2-3 cm) was *not* necessary. Stock were rotationally grazed and controlled pastures were always less than 20 cm before grazing. Once these levels were exceeded, then pasture control was lost quickly.

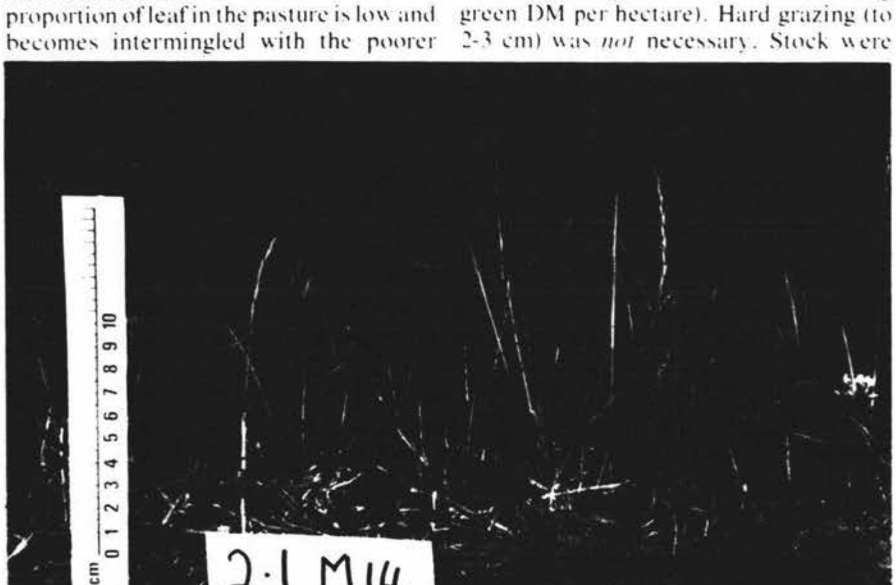
These results suggest that animals can be grazed to levels which will ensure very good stock growth and still maintain pasture control. However, in the author's trial, animal performance was not measured and further work is required in this area.

Results of studies at Whatawhata Hill Country Research Station suggest that on steep hill country, these levels may have to be reduced. In this situation, cattle can have an important role in pasture control. If pastures on the grazed area of the farm

A laxly grazed pasture, the only one (of the three photographed here) that could be described as 'uncontrolled'. The photograph was taken in mid-December after three months lax (initially to 12cm) grazing.

exceed the levels stated, then animals should *immediately* be restricted to a smaller area. This will maintain pasture control at least on the areas currently grazed. The other areas can be topped or used for hay or silage. If this is not possible, then they should simply be left and grazed later in the summer. On hill country, the steep areas should be those on which pasture control is maintained by grazing. These are the areas that will suffer most quickly from weed ingress and loss of subsequent production.

Unfortunately, pasture control cannot be achieved by only a few well-timed hard grazings or toppings. Because reproductive development and high pasture growth rates occur over a period of at least 6-8 weeks in spring, grazing pressure must be maintained over the whole period. To this end, set stocking in spring may be more successful than rotational grazing as the grazing of individual plants is more frequent. ●



Once again, a photograph taken in mid-December after three months grazing. In this case, the grazing intensity is described as moderate (initially to 8-9cm).

EFFECTS OF SPRING GRAZING MANAGEMENT ON HERBAGE MASS AND SWARD CHARACTERISTICS IN A RYEGRASS WHITE CLOVER PASTURE

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SUMMARY

The effects of grazing intensity and frequency were investigated on a ryegrass/white clover pasture. Large differences in herbage mass between treatments arose mostly from ryegrass reproductive stubble during spring and mid-summer and from dead reproductive stubble during mid-summer and early autumn. Leafy, vegetative pastures were achieved during the reproductive growth period by maintaining a sward residual of less than 500 kg leaf DM/ha (sward height 9 cm) and a grazing interval of less than 14 days (pre-grazing height 20 cm). The evidence suggests that reducing the mass or size of individual reproductive tillers can be equally effective as that of reducing the number of reproductive tillers in maintaining the pasture in a leafy state.

KEYWORDS: grazing intensity, grazing frequency, spring pasture management, ryegrass reproductive development, herbage mass, tillering.

INTRODUCTION

Sward conditions, such as herbage mass, the proportion and distribution of herbage mass components within the canopy, height and species composition will influence herbage intake by grazing animals (Hodgson 1982). The intensity and frequency of grazing, especially over the late spring/early summer period when grasses are in the reproductive stage of development, can have a major influence on sward conditions and therefore animal intake and performance (Hughes 1983, Hughes et al 1984).

Korte et al (1982, 1984) suggested that late spring grazing should aim to prevent reproductive development of the grass component, thereby obtaining a more leafy, vegetative sward by summer. This can be achieved by hard grazing which removes the reproductive tillers. Hard grazing, however, is undesirable over this period because animal performance will be reduced (Rattray et al 1982).

This paper reports a grazing experiment investigating a range of grazing intensity and frequency treatments during reproductive growth to find a grazing regime less likely to reduce animal performance but still maintain pasture in a leafy state through summer.

METHODS

The experiment was conducted on a ryegrass/white clover pasture at Massey University,

Palmerston North, New Zealand. There were six grazing treatments, comparing three intensities: Hard (H), Medium (M) and Lax (L) with residual leaf mass of approximately 150, 450 and 750 kg DM/ha, at a 14 day regrowth interval (designated as H 14, M 14, and 243
L 14 respectively), and four frequencies at the medium level of defoliation at 7, 14, 21 and 28 day regrowth intervals (designated as M 7, M 14, M 21 and M 28 respectively), M 14 being the common treatment across both frequency and intensity. There were four replicates.

The plots each 180 m², were grazed by sheep over one day. The differential grazings (treatment period) lasted 12 weeks (23 September 1983 - designated day 0 - to 16 December 1983 - designated day 83) after which all plots were grazed to a residual of 150 kg leaf DM/ha. Subsequent pasture performance was assessed under a common grazing regime (residual of approximately 450 kg leaf DM/ha) on 22 January 1984 (day 119). Final data presented in this paper was collected on 10 March 1984 (day 168).

Details of the experiment are presented elsewhere (Butler 1985).

RESULTS AND DISCUSSION

Total standing herbage measured on days 83 and 119 showed large differences between both intensity and frequency treatments, and the differences were maintained to, at least, day 168 (Table 1).

Table 1. The effects of grazing intensity and frequency on sward components (kg DM/ha) at the end of the treatment period (day 83) and during subsequent regrowth periods (days 119 and 168).

	Intensity			Frequency			
	H 14	M 14	L 14	M 7	M 14	M 21	M 28
Day 83							
Leaf	841 a*	1234 ab	1224 ab	1085 ab	1234 ab	1307 bc	1684 c
Stubble - Repro	143 a	663 a	2302 b	324 a	663 a	1727 b	2008 b
- Vege	507 a	654 a	745 a	1052 b	654 a	650 a	1130 b
Dead - Stubble	344 a	411 a	607 ab	269 a	411 a	433 a	769 b
- Leaf	390 a	935 b	1335 c	903 b	935 b	793 ab	1402 c
Total	2225 a	3897 b	6213 d	3633 b	3897 b	4910 c	6993 d
Day 119							
Leaf	1852 a	1564 a	1281 a	1538 a	1564 a	1446 a	1346 a
Stubble - Repro	323 a	235 a	369 a	572 a	235 a	156 a	71 a
- Vege	1168 a	913 a	854 a	948 a	913 a	845 a	909 a
Dead - Stubble	123 ab	500 ab	2275 c	379 ab	500 ab	1105 bc	1735 bc
- Leaf	464 a	725 a	1338 b	692 a	725 a	760 a	1811 c
Total	3930 a	3937 a	6117 b	4130 a	3937 a	4332 a	5872 b
Day 168							
Leaf	1660 a	1737 a	1111 b	1757 a	1737 a	1781 a	1732 a
Stubble - Repro	33 a	0 a	0 a	63 a	0 a	128 a	0 a
- Vege	900 a	857 a	630 a	930 a	857 a	913 a	817 a
Dead - Stubble	168 a	292 a	1594 b	248 a	292 a	426 a	1352 b
- Leaf	976 a	1007 a	1673 b	1033 a	1007 a	963 a	1605 b
Total	3737 a	3893 a	5008 bc	4031 a	3893 a	4211 ab	5506 c

By the end of the treatment period (day 83) on a proportional basis there was a greater green vegetative herbage mass (leaf + stubble vegetative) in the H 14, M 14 and M 7 plots (42, 48 and 58% respectively) than the L 14, M 21 and M 28 plots (31, 39 and 40% respectively). In spite of differences between swards during the treatment period, by day 168 all the other plots except L 14 had similar leaf mass, reflecting differences in leaf accumulation over this period (Butler 1985).

The effects of grazing intensity and frequency on tiller density and size are presented in Table 2. At the end of the treatment period (day 83), vegetative tiller numbers on the laxly (L 14) and infrequently (M 21 and M 28) grazed plots were approximately 19-45% of the hard (H 14) and more frequently (M 7) grazed plots. However, by the end of the trial on day 168 all the swards except L 14 had similar vegetative tiller densities, reflecting a fairly sensitive response by tiller numbers to defoliation.

Spring/early summer grazing management should attempt to prevent large increases in stemmy reproductive stubble. In the present experiment treatments H 14, M 14 and M 7 achieved

*FOOTNOTE: Treatment values with different letters are significant at the 5% level of probability.

this with their pre-grazing herbage remaining largely vegetative. Most research findings have emphasised the importance of reducing the number of reproductive tillers through a well timed hard grazing (Korte et al 1984, Hughes 1983) or mechanical topping (McDonald 1984). 244 However, hard grazing is unlikely to be adopted by farmers over this period because of the adverse effect on animal performance. Results from the present experiment clearly show that a medium level of pasture utilisation (M 14) can provide a similar degree of "control" as that of hard grazing (H 14).

When comparing across the intensity and frequency treatments the common grazing regime (M 14) provided an explanation on the possible reason for this response. The reproductive stubble (Table 1) and the individual reproductive tiller mass (Table 2) of M 14 were similar to the "controlled" pastures of M 7 and H 14. On the other hand, the density of reproductive tillers in M 14 was similar to those of the "uncontrolled" pastures of L 14, M 21 and M 28 (Table 2). Thus, it appears that the difference in the quantity of reproductive stubble that had accumulated by day 83 (Table 1) was largely due to difference in the size of the individual reproductive tillers rather than the density of these tillers.

Table 2. The effects of grazing intensity and frequency on tiller characteristics.

	Intensity			Frequency			
	H 14	M 14	L 14	M 7	M 14	M 21	M 28
Day 83							
Reproductive tiller mass (mg/tiller)	40 a*	60 a	180 c	50 a	60 a	130 b	140 bc
Density (m^2)	600 a	1400 b	1400 b	600 a	1400 b	1400 b	1800 b
Emerged inflore-scence tillers/m^2	20 a	160 b	1010 e	130 b	160 b	380 c	530 d
Vegetative tillers/m^2	11400 bc	10200 abc	7300 a	13400 c	10200 abc	7200 a	8300 ab
Day 168							
Vegetative tillers/m^2	10520 b	12510 b	5900 a	10610 b	12510 b	11910 b	10860 b

This finding points to the possibility of using the size of the reproductive tillers as an alternative to using tiller numbers as a criteria for spring pasture management. The M 14 treatment corresponded to a grazing regime where the sward height was not allowed to exceed 20 cm and grazed down to at least 9 cm every 14 days. These levels are in general agreement with observations made on hill country and dairy pastures in New Zealand (Sheath & Bryant 1984, Sheath & Bircham 1983).

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*FOOTNOTE: Treatment values with different letters are significant at the 5% level of probability.

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