THE EFFECTS ON PASTURE OF THE WINTER GRAZING

OF DRY DAIRY COWS

A thesis

presented in partial fulfilment of the requirements

for the degree

of

MASTER OF AGRICULTURAL SCIENCE

at

Massey University

P. N. P. MATTHEWS

1971

ACKNOWLEDGEMENTS

I should like to extend thanks to the following people who assisted in one form or another in the course of experimental work or in the compilation of this thesis :

Firstly, I should like to thank Professor B.R. Watkin who supervised this study and supplied encouragement and guidance at all times.

To Mr A.G. Campbell and Mr D.B. Edmond for helpful discussion, criticism and material assistance.

To Mr K.E Jury for advice on statistical analysis and for carrying out the regression analysis presented. Also to Professor R. Mundford for making available his multi-purpose analysis of variance programme.

To Mr I.P.M. MacQueen for supplying experimental animals and the land required for both experiments and to Mr T. Lynch and his staff at No. 3 Dairy for assistance in drafting and moving stock. Also to my father, without whose assistance the volume of work associated with each grazing period would have been excessive.

To Mrs V. Swan for the unenviable task of typing the final copy of this text.

Lastly, I must thank my wife Frances, for the understanding and sacrifices made, during the writing of this thesis.

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INTRODUCTION

With the demand for higher production, but probably
more from economic necessity, stocking rates on New Zealand
dairy farms have increased markedly over the past ten years.
The average herd size has over this period increased from 57
cows in 1960 to an estimated 98 cows in 1970 (N.Z. Dairy
Board, 1970); this figure however takes no account of any
increase in farm size over this period.

Increased stocking rates on a fixed area of land has
not been associated with similar increases in pasture
production, indeed, the reverse may be the case (Campbell, 1966;
Holmes, 1962; Morley 1966). The increased production has
been a function of increased utilization of the pasture grown
(Campbell, 1966). With such trends management decisions with
regard to pasture and animal become critical, mistakes having
long reaching repercussions. A critical period on all seasonal
dairy farms is over the winter when management decisions can
affect butterfat production for the entire lactation (Wallace
1958). Increased stocking rates have heightened this wintering
period as a result of mainly two factors :

(i)   An increased milking herd means lower pasture
surpluses in the spring, hence lower levels of
conserved fodder for periods of low pasture production.

(ii)   It is at this time of the year that damage to
pastures through grazing appears most severe.

Increased stocking rates mean a larger number of animals over the winter but a greater reliance on pasture for winter fodder also means increased grazing over this period. This trend may be eased in some cases by later calving.

Over the winter period it is necessary to equate pasture production with animal requirements both before and after calving; at the same time it is necessary to be aware of the effects grazing is having on future pasture production as a result of defoliation, treading and excretion by the grazing animals.

Most aspects of grazing ecosystems in the New Zealand environment have been studied in isolation, e.g. animal requirements (Hutton 1962), intake (Wallace 1958), defoliation (Brougham 1959), treading (Edmond 1966) and excretion (MacDiarmid 1969). Such experiments cannot take account of interactions that may be present; few attempts have been made to bring these factors together and study in any detail the implications of management systems in terms other than one or two marketable animal products.

The experiments presented in this thesis were designed to provide information on some pasture aspects of grazing dry dairy cattle over the winter period; in terms of pasture 'utilization' at grazing and its regrowth over the late winter – early spring. Study was on one soil type in one season.

REVIEW OF LITERATURE

1.1 Introduction

Winter grazing of dairy cattle involves a wide range of interrelated aspects. Agronomically it covers the growth, defoliation and regrowth of pastures, the effect of the animal upon pasture and soil while grazing is taking place, and the grazing management techniques employed.

This review will deal with the growth, defoliation and regrowth of pastures from a physiological and morphological point of view, then will extend these aspects to the grazing situation with animal influences of defoliation, treading and excretion. More specific aspects of wintering will then be covered; the pasture productivity over the winter, the requirements of livestock over this period and how all these aspects are interpreted in the practical situation.

1.2 Pasture growth with defoliation

With defoliation of a pasture sward the interest lies in three aspects :

    i   The growth and death of plant material

    ii   Changes in botanical composition

    iii   The persistency of the sward.

Studies involving various levels of intensity and
frequency of defoliation have been numerous (e.g. Brougham,
1956; 1959; 1960; Reid, 1959; 1962) and frequently the
subject of review articles (e.g. Humphreys, 1966; MacLusky
and Morris, 1964; Spedding, 1965). Literature can be cited
showing advantages in pasture production for less intensive,
more intensive, less frequent, more frequent or practically
any combination of frequency and intensity of defoliation. It
is not proposed therefore to review these experiments as such,
but to review current knowledge on the underlying physiological
and morphological changes that take place within a plant
community when it is defoliated.

1.2.1 The growth and death of plant material

The primary limitation to biological production is set by
photosynthesis (Blackman and Black, 1957). This means that when
all factors are optimal for growth, the maximum growth rate of a
plant or sward will be determined by the quantity of light being
intercepted by the foliage (Bohning and Burnside, 1956; Brougham,
1956). Photosynthesis in individual leaves falls with increasing
light intensity received on the leaf surface (Hesketh, 1963) and
any light falling on bare ground is wasted (Brougham, 1956).
The maximum growth rate of a sward will occur when all incoming
radiation is intercepted by the plant canopy in such a way that
the maximum leaf area is exposed to the minimum light intensities
necessary for photosynthesis. Brougham (1956) found the critical
value to be 95% interception of incident light and Bohning and
Burnside (1956) found the minimum light intensity to be in the
range 400 - 500 foot candles.

Species differences exist in the Leaf Area Index

(LAI)* required to intercept 95% of incident light (Brougham,

1956) which appears due to their growth form, in particular

the orientation and shape of their leaves. The time taken for

a sward or a species within a sward to reach the point of

maximum growth rate will determine the productivity of both,

while within the sward, it will also determine the competitive

ability of individual plants and/or species. Due to the

exponential nature of plant growth (Brougham, 1956) advantages

(e.g. leaf area) gained in the first few days will be maintained

until such time as some other factors (e.g. competition for

light) brings the phase to an end.

Initially, regrowth will be determined by the meristematic

activity of the sward (i.e. number of growing points)(Langer, 1963).

The rate of regrowth will be determined by the reserve status

(usually taken as meaning the soluble carbohydrate level) within

the plant and the residual leaf area (RLA) remaining on a plant

or tiller following defoliation (May, 1960).

The meristematic activity will be determined by the

previous management of the pasture (Brougham, 1959; Mitchell

and Coles, 1955), season, and the number of apical meristems

removed or damaged during defoliation (Campbell, 1961). During

the vegetative state it is unlikely in most common species of

pasture plants that the apical meristem will be damaged by

grazing (Campbell, 1961). With stem elongation associated with

flowering the apical meristem of grasses becomes susceptible to

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* Area of leaf per unit area of ground. Measurement of
  one side of each leaf only (Watson, 1947).

removal (Campbell, 1961) and once removed the potential production of that tiller is lost (Langer, 1957; 1959). Removal of flowering stems may induce other vegetative growing points to differentiate and produce heads (Langer, 1957). New growth develops from vegetative tillers at the base of the tiller destroyed (Langer, 1963) but it is a relatively slow process (Davies, 1956). Defoliation not only influences tillering through removal of the growing point but also through the removal of leaf material. Defoliation re-establishes the interdependence of tillers for a short time, completely defoliated tillers benefitting from assimilate translocated from undefoliated tillers (Marshall and Sagar, 1965), but defoliation may induce a temporary reduction in tillering (Davidson and Milthorpe, 1965). This reduction is perhaps due to increased demands for substrate by existing tillers, as Alberda (1966) showed the reduction to be most marked in plants with low carbohydrate levels. On the other hand the improved light regime following defoliation may lead to increased tiller numbers (Mitchell and Coles, 1955).

The fluctuation of soluble carbohydrate levels following defoliation and during regrowth has led observers to place considerable importance on the necessity for having high levels of reserves immediately prior to defoliation (Weinmann, 1952). Since the awareness of the significance of leaf area to growth (Brougham, 1956; Davidson and Donald, 1958) differing degrees of importance have been attached to the role of reserves. Discussion in the late 1950 s as to the role of reserves centred upon whether they are used predominantly as a respiratory

substrate (May, 1960) or used directly in new shoot and root growth as had been assumed in the past (Weinmann, 1961). If reserves contribute to new growth advantages may be gained by having extensive reserve levels, if not, then there is little to be gained by having reserves in excess of the respiratory needs of the non-photosynthetic organs. Not all soluble carbohydrate appears however to be available as a respiratory substrate (Alberda, 1966). The level of soluble carobohydrate reserves at any one time are in fact a balance between the rate of photosynthesis (both past and current), the amount of photosynthate produced, the rate of respiration, the rate of translocation to sinks, and the rate of growth (Davidson and Milthorpe, 1965). The build up of carbohydrates are associated with reduced growth rates (Brown and Blaser, 1965; Sheard, 1968) and it is argued that this increased level may represent growth not being made rather than a contribution to growth (Blaser, Brown and Bryant, 1966). This contention is supported by the general reduction of carbohydrates in storage organs following application of nitrogenous fertiliser (Sheard, 1968) and the possible inhibition of photosynthesis by high concentrations of soluble carbohydrates (Moss, 1962; Went, 1958).

Recent literature implicates stubble reserves in new leaf growth (Ehara, Maeno and Yamada, 1966; Marshall and Sagar, 1965), especially the carbohydrates within expanding leaves (Davidson and Milthorpe, 1966 b). A casual role for reserves in the formation of new tissue has not however been fully established. There appears to be little possibility of root

reserves contributing to new leaf growth (Marshall and Sagar, 1965). Root reserves appear to be used as respiratory substrates in the roots and possibly for any root extension that occurs (Davidson and Milthorpe, 1966 b; Marshall and Sagar, 1965); these may be supplemented by translocation from the stubble reserves and later from new photosynthates (Davidson and Milthorpe, 1966 b). The oldest expanding leaves have first priority in the use of assimilate and therefore leaf expansion is reduced relatively less than tiller or root growth, which may stop completely following defoliation (Davidson and Milthorpe, 1966 b).

Defoliation has often been observed to affect root growth adversely (May, 1960; Davidson and Milthorpe, 1965). This decrease in root extension is probably a direct result of the removal of the primary source of carbohydrate. Regrowth may be limited by the rate of nutrient uptake during the recovery period (Davidson and Milthorpe, 1966 b) and some of the responses to severe defoliation which have been ascribed to reserve shortage, may in fact be due to the limitation of mineral uptake (Davidson, 1963). The significance of this reduced uptake will depend on the internal nutrient status of the plant prior to defoliation (Davidson and Milthorpe, 1966 b). Reduction in leaf area and root extension will also impair the soil moisture usage of a defoliated plant (Jantti and Kramer, 1956).

Substances other than soluble carbohydrates have been implicated as reserve substances (Davidson and Milthorpe, 1966 a; Alberda, 1966) and are thought to be predominantly of a protein

nature. These non-carbohydrate reserves may contribute a
large portion of the total plant reserves, especially when
the level of the carbohydrate is low (Davidson and Milthorpe,
1966 a). The advantage of there being adequate internal
nitrogen (N)* reserves and carbohydrate/N ratio rather than
high carbohydrate, low N reserves have been stressed (Sheard,
1968).

The direct contribution of reserves to new photosynthetic
tissue may be small and transitory (Davidson and Milthorpe, 1966 b)
but regrowth may depend upon them entirely in the first instance.
Their overall importance to regrowth will probably remain
controversial as separation of the effects of RLA and reserves
in regrowth is difficult because :

(i)   When rapid initial regrowth is attributed to
       high levels of reserves, early leaf formation
       immediately becomes a confounding factor.

(ii)   Green leaf remaining after defoliation absorbs
       light and photosynthesises, but may also
       contain soluble carbohydrates which could
       provide a ready energy source and material
       for regrowth.

Intensive defoliation will be compatible with high
production provided the frequency of defoliation is such that

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* For the remainder of this text all chemical elements
  will be referred to by their conventional abbreviations.

reserve levels and adequate root growth can be maintained
(Reid, 1959). Conversely frequent defoliation is acceptable,
provided adequate leaf capable of photosynthesis remains to
supply the energy requirement after defoliation. If frequency
is increased for a given cutting height, it can generally be
concluded that defoliation will result in lower yields
(Humphreys, 1966). Frequent and intensive defoliation will not
be acceptable in most instances as RLA will be non-existent,
reserve levels will be small and root growth depressed. Plants
may however adapt to such a management system by assuming a more
prostrate growth habit, thus providing increased RLA below the
cutting height and increased stubble reserves (e.g. Kydd, 1966).
More prostrate plants may be already adapted to close defoliation;
as shown by Radcliffe, Dale and Viggers (1968) browntop hill
pastures obtained highest D.M. production under defoliation to
ground level. No one management system will however be
acceptable at all time of the year (Sears, 1956) a factor which
is difficult to interpret experimentally in cutting trials.

Hunt and Brougham (1967) studied the structure of perennial
ryegrass swards frequently (weekly) but leniently (so 90 - 95%
of incident light was being intercepted after cutting) defoliated
in late summer. Owing to increased dead matter and sheath
material, and a decrease in green leaf in the sward, they
concluded that photosynthetic efficiency of the sward would fall,
and that a lenient cutting system is unlikely to provide the
maximum yield of harvestable dry matter in many environments, or
over long periods of time. Changes in canopy characteristics will

alter the efficiency of light utilization as photosynthetic areas are not equal in their efficiency; young (Gabrielson, 1948) and old (Stern, 1960) leaves are less efficient. The proportion of photosynthetic to non-photosynthetic components and their distribution within the canopy will directly affect light utilization (Warren Wilson, 1960). Wheeler (1962) considers hat light use is only important in periods when light limits growth and that in most pastoral environments these periods are of short duration.

At some stage during regrowth, growth will be curtailed or limited by inter- and intra-specific competition for one or more growth factors (e.g. light, nutrients, water, etc.).

Leaf senescence due to the natural genetically controlled life-span of individual leaves (Leopold, 1964) and imposed environmental factors such as light (Brougham, 1958), moisture deficit, high temperature, and nutrient deficiencies (Leopold, 1964), means that dry matter losses will be occurring within the sward. The life-span of both clover (Brougham, 1962) and ryegrass (Hunt and Brougham, 1966) appears to vary with season being greatest in the winter. Hunt (1968) studying leaf death rates in a clipped ryegrass-white clover pasture obtained maximum leaf death rates of 56 lb D.M. per acre per day and 27 lb D.M. per acre per day in the spring and autumn respectively. Maximum rates occurred after 68 days regrowth in the spring and 59 days in the autumn. With senescence, not all D.M. is lost, as at senescence the dry weight of a leaf is approximately 50% of their maximum weight (Brougham, 1958). Although animals

select against dead material (Arnold, 1960) this material may constitute a large proportion of their diet (Lancashire and Keogh, 1964). The nutritive value of this dead matter appears to be unknown. Rates of leaf senescence will determine the potential for D.M. decomposition in a sward. Decomposition under New Zealand conditions appears slower in summer than in either spring or autumn. This dead matter accummulation over the summer period may result in the dead matter component accounting for 30% to 50% of the total D.M. present in early autumn (Campbell, 1964). Clover leaves decompose faster than those of ryegrass (Hunt, 1968), the extent depending on season and stage of growth.

Following defoliation, leaf death and decomposition will eventually, during the latter stages of regrowth, equal leaf production so that a ceiling production will be reached. Loss rates at ceiling yields for white clover in early spring (Brougham, 1958) and Italian ryegrass in early winter (Hunt and Brougham, 1966) have been calculated at 20 lb and 10 lb D.M. per acre per day respectively. Hunt (1968) found dead material in a clipped ryegrass/white clover pasture decomposed at approximately 30 lb D.M. per acre per day in the spring and 16 lb D.M. per acre per day in the autumn.

The stage of growth at which a sward is defoliated will therefore be an important factor in influencing the extent of leaf death and decomposition during regrowth and the accumulation of dead material in the sward over a number of regrowth periods.

1.2.2 <u>Botanical Composition</u>

Pastures have often been described as being in a precarious equilibrium (Sears, 1956) with quite small changes in any one factor rapidly leading to marked changes in pasture yield and composition. To be successful a pasture is required to :

(i) Produce the maximum sustained yield of utilizable nutrients.

(ii) Maintain an appropriate legume/grass balance.

For sustained productivity, Morley (1966) considers that maintaining the stability of a plant community is essential. Stability as described by Morley may not be so important under New Zealand conditions as those he experienced at Canberra, as the New Zealand environment is more suited to perennial species and high stand density. The ability of a plant or species to compete successfully following defoliation will depend upon its physiological reaction to defoliation relative to other plants or species in the sward. Defoliation can alter the competitive relationships between species through modification of the environment and differential species vulnerability to leaf removal (Humphreys, 1966). Species susceptibility to defoliation will thus be determined by the seasonal growth potential of the species and the timing of defoliation.

Competition among plants for space probably does not take place as before such a point is reached competition for light, water, nutrients etc. or some combination of factors will limit

growth. Light is often a dominant factor governing composition
of a sward (Blackman and Templeman, 1938) and a species able to
reach a greater size prior to full utilization of light will
normally hold the competitive advantage. The sensitivity of
clover to light competition (Stern and Donald, 1962) is well
known and necessitates control of the taller grasses to reduce
this competition. Clovers will respond rapidly to any change
in light environment (Stern and Donald, 1962). Hunt (1968)
found shading of the lower canopy appeared to enhance the
senescence of clover leaves but could not find evidence for
a comparable effect on ryegrass leaves.

As discussed by Holmes (1962) a prostrate habit of growth
or the ability to develop such a growth form will enable a
species to survive, compete and produce when subjected to
frequent intensive defoliation. In general it appears that
continuous heavy grazing is detrimental to acceptable
perennials, with them being replaced by annuals or bare ground;
with some form of spelling however heavy usage may be compatible
with botanical stability (Morley, 1966). Used intelligently
hard grazings of plant communities at particular times of the
year are of value in changing dominance to species that tolerate
the subsequent climate (Brougham, 1960; Campbell, 1964).

1.2.3 Persistency of a sward

Old and dying tillers must be continually replaced by new
tillers if a grass species is to survive (Davidson and Milthorpe,
1965). Tillering is most active in the autumn months and

management systems favouring grass growth and, in particular, tillering over this period will ensure survival (Campbell, 1961). Autumn tillers will be vernalized over the cooler winter months and will form the bulk of the fertile tillers in the following spring (Campbell, 1961). White clover can survive vegetatively within a sward provided spelling occurs and competition from grasses is kept to a minimum. If, however, the legume is an annual, a similar management system involving intensive defoliation may lead to its disappearance from the sward (Morley, 1966).

1.3   The influence of the animal upon pastures

The grazing animal defoliates a sward, treads it, and deposits dung and urine upon it. These separate factors of grazing, treading and excretion act together, but their relative importance will depend upon local conditions.

1.3.1 Grazing

Sections 1.2.1 and 1.2.2 have outlined aspects of pasture production and regrowth following defoliation mainly by mechanical methods. What happens however when the defoliation is carried out by free grazing animals? The previous outline holds but as will be discussed in this section the interpretation will be somewhat modified.

Unlike cutting treatments, with grazing there will be changes in the duration of each period of defoliation and in

periods allowed for regrowth. Defoliation is not instantaneous and a tiller or plant may be defoliated several times during a grazing period, while others may not be defoliated at all. With the grazing animal there is no control over the height of defoliation of individual tillers or plants, but stocking rate allows a modicum of control over the overall 'average' intensity. Unless some rotational system is adopted there is also no control over the frequency of grazing. Under set stocking, defoliation becomes even more confused and, therefore, even harder to compare with the situation under mowing. Hodgson (1966) found that when set stocked, increasing the stocking rate of hoggets from 19 to 30 per acre increased the defoliation of tillers on average from once every 11 - 14 days to once every 7 - 8 days. The intensity of grazing will be affected by changes in the physiological demands of the stock and in stocking rate throughout the year as well as by variation in pasture production (MacLusky and Morris, 1964).

In his review McClymont (1967) says... "A grazing ruminant commonly has available to it a wide range of potential food in the form of different plant species from grasses to trees, each with its young and old leaves, stem, seeds and other components, each with particular physical, chemical and so nutritional characteristics, and each with different densities."

Improved pastures contain however a smaller number of species, there being in some cases only a single species or strain. Selection is possible even within a single plant

which makes it necessary to know, what an animal will select,
why it is selected and what effect this selection has upon the
sward. When grazing, movement is on a horizontal plane and
selection in a vertical plane (Arnold, 1960). Sheep and cattle
will select leaf in preference to stem and young leaves (green)
in preference to old leaves (dead). This selection is usually
higher in protein, phosphorus, soluble carbohydrates and gross
energy and lower in lignin and structural carbohydrates, than
the pasture as a whole (Arnold, 1960; Fontenot and Blaser 1965).
Arnold (1962) considers that selection between species is
unlikely to be a direct result of any one of these chemical
differences.

Sheep have no fixed reaction to species, it will change
from season to season (Arnold, 1964). It is perhaps the
physical aspect of the plant community that is of importance
in the animal's selection. Little selection is practised on
young, mainly leafy growth, but as herbage on offer increased
in age and maturity, selection became more pronounced (Arnold,
1960). In a mixed sward the species with the least mature
herbage at any one time is normally preferred, possibly due to
its degree of liquification in relation to ease of harvesting
(Arnold, 1964). Availability in terms of frequency of occurrence,
relative yield and accessibility of a plant or species, will
obviously motivate the animal's selection (Arnold, 1964). With
abundant forage supply, selectivity may be freely expressed.
As availability decreases so will selectivity and less acceptable
forage must be eaten. The animal appears to compromise, so that
whilst eating previously neglected species a high proportion of

its total grazing will be on favoured species of low
accessibility (Arnold, 1964). Grazing pressure will have
little influence on the preference ranking of species,
relative acceptabilities between species will be reduced,
but in the extreme when only a really disliked species remains,
animals may prefer to starve.

Differences occur between animal species and also between
individuals of a flock or herd in their selectivity. For
example at a low stocking rate on the same small pasture, the
proportion of grass in the diet of sheep ranged from 10% to
80% (Arnold, 1964). Sight plays a minor role in selection,
with taste, smell and touch involved to a greater extent
(Arnold, 1966). Balch and Campling (1962) in their review
concluded that appraisal of food, especially by taste and
associated senses is of much less importance when a single
food is given without choice. Selection must be the result
of innate behaviour plus learning (McClymont, 1967).

Non-uniform grazing and preferential species use will
mean that the seasonal response of the sward components may
alter under grazing. Selection will alter the characteristics
of the canopy at the expense of the most photosynthetically
efficient component, green leaf. If grazing is only light
giving rise to high animal selectivity, then botanical
composition changes following grazing will be away from the
desirable species. Clover is preferred to ryegrass, leading to
overgrazing of clover (Brougham, 1966). Varying proportions of
the terminal growing point of the clover stolons will be removed

and clover regrowth may be delayed in comparison to the grass
species while the clovers re-establish meristematic activity.
The regrowth is then characterized by increased development of
axillary meristems, followed by an increase in the number of
leaves per unit area of sward. These leaves will be smaller
in all dimensions, particularly petiole length, making the
clovers increasingly vulnerable to competition; particularly
during the colder months of the year (Brougham, 1966).

1.3.2 Treading

Treading may be defined as the effect of the animals'
hooves upon their surroundings. On one hand there is direct
action upon the pasture species, and on the other indirect
action on pasture production through changes in soil properties.

Experimental appreciation of treading has been sparse.
Treading was noted in some early experiments and discussions;
these include the influence of treading on secondary growth in
North Island hill country in New Zealand (Levy, 1926) and
ecological studies of areas of obvious treading namely tracks
and gateways (Bates, 1930; 1935; Davies, 1938). Early German
work (Kleckia, 1937) studied species susceptibility to treading.
Treading has also been discussed with reference to soil erosion
in the Hawkes Bay (Campbell, 1950) and grazing behaviour (Hancock,
1950). More recent work, presented in the following sections has
attempted to put a quantitative value upon the impact of treading
in the animal-pasture-soil ecosystem.

Li (1956) describes what takes place when a force is applied to a soil as follows :

" i. If applied stresses exceed the shearing strength or resistance of the soil, local failure begins and the load starts to sink into the soil.

ii. As the load sinks, soil is pushed downward and outward mobilizing more and more resistance. Settlement stops when equilibrium between stresses and resistance is reached. "

Estimates of static loads exerted by livestock are: 9.2 lb/in^2 for sheep (Lull, 1959), 23.9 lb/in^2 for cattle (Lull, 1959), and 16.21 lb/in^2 for mature Jersey cows (Myers, 1956). Loads exerted by Friesian cattle do not differ significantly from those of Jersey cattle (Myers, 1956). Dynamic loads are greater than static loads and Myers (1956) considered this increase to be twofold, which will give a value of 32 lb/in^2 for Jersey cows. Values of up to 50 lb/in^2 for cattle have however been quoted (Edmond, 1958 c; Sears, 1956).

The extent of treading can be visualised from cattle making approximately 8,000 - 10,000 foot impacts per day each of 14 in^2 (Farris, 1954) giving a total area trodden of 0.02 acre per day (O'Conner, 1956). Areas covered will be dependent on behavioural responses caused by pasture availability and nutritional demands of the animal (Arnold, 1960; England, 1954), weather (England, 1954; Hancock, 1953), and the physiological state of the animal (Cresswell, 1960; Farris, 1954). Management

appears to have little influence on distances walked
(Cresswell, 1960; Waite, McDonald and Holmes 1951) but
will determine the intensity of treading through the stocking
rate employed.

Bates (1935) noted that treading and puddling exerted
a selective influence upon the grasses present on tracks and
roadways, eliminating those not structurally adapted to
withstand the injury of the treading and puddling. In
practice however, these tracks and roadways are generally
regarded as acceptable within the management framework of
grazing even though treading is detrimental to the areas
concerned. It is the less obvious treading; that which takes
place whenever an animal makes contact with the pasture and/or
soil with a hoof during normal grazing, which is of greatest
interest. Observations have shown that yield differences of
even 30% are not easily seen and so much treading damage will
pass unnoticed, or its extent will not be fully appreciated
(Edmond, 1966).

Sears (1947) discussing aspects of pasture growth and
utilization said, ".... under normal conditions the 'hoof
cultivation' and pressing of the crowns of the plants into
the ground is beneficial, but in excess this can open up a
sward and 'pug' the soil so that pasture growth is seriously
impaired and weeds obtain a start....."

In an endeavour to attempt a more critical estimation
of treading damage, a technique was developed by Edmond (1958 c)
for isolating treading from other effects of the grazing animal

on pasture. This technique consists of driving groups of animals along narrow fenced plots of such a width that the passage of one animal is equivalent to one animal per acre per day. Pastures are mown prior to treading when grazing treatments are simulated by the passage of a group of animals along these plots, in both directions, until the desired intensity is reached. A grazing treatment incorporating any time span will be simulated in a space of minutes or at the most hours.

Owing to the paucity of data from other sources, the majority of discussion to follow is derived from experiments based on Edmond's technique therefore it warrants closer appraisal. The treatment suffers from several limitations in terms of its interpretation into a practical situation :

i. Treading is only in two directions and takes place over a short period of time, whereas in practice, treading will be multi-directional and may be spread over a period of days or weeks. Recovery of individual tillers between each separate impact is not possible.

ii. Treatment is on a defoliated sward, making the sward more susceptible to injury (O'Connor, 1956). In the paddock situation treading will take place at varying levels of defoliation.

iii. There is an underlying uncertainty of the quality of the treading. Is the force applied to the sward, and the cutting action of hooves applied by sheep in a driven mob similar to those of freely roaming undisturbed animals?

iv. The treatment levels applied have at the higher
levels diverged from practical meaning. 'Stocking
rate equivalents' * above 10 or 12 sheep/acre may
suffer this criticism. The technique has been used
with levels as high as 32 (Edmond , 1964) and 48
(Brown, 1968) sheep equivalents per acre. Pasture
responses at these high levels are however, of
interest in our basic understanding of a plant
community.

v. If differential regrowth periods were allowed
according to the number of sheep used, then the
higher 'stocking rate equivalent' results would
become more acceptable. Treatments would then
become estimates of different methods of applying
lower stocking rates, but would be difficult to
interpret experimentally, owing to changes in soil
properties with time and seasonality of pasture
growth.

vi. No estimates have been possible of the immediate
effects on the pasture and its utilization by the
animal as against its regrowth.

This was however the first and possibly the only attempt
to study treading in complete isolation. It is basic research
in terms of plant response, comparable with small plot trials

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* As determined by Edmond (1958 c)

$$\text{'Stocking rate equivalent'} = \frac{\text{number of sheep/treatment (nd)}}{\text{Time in days between successive treatments (d)}}$$

and is expressed as n sheep / acre.

on for example, light utilization, dry matter production and dry matter losses.

As with small plot trials the main criticism is not with the experimental method but with the extrapolation many people have been prepared to make from results of this basic research, to the practical situation.

Treading has been shown to produce a significant and progressive reduction in the yield of all species as stocking rates increase (Edmond, 1958 c; 1964; Brown, 1968), the extent of this reduction varying between experiments (Edmond, 1958c; 1962; 1963; 1964; 1966; Brown, 1968). Table I presents results of treading a short-rotation ryegrass (Lolium perenne x Lolium multiflorum), white clover pasture, with varying 'stocking rate equivalents' during the spring.

TABLE I : Herbage yields (lb D.M./acre) following treading treatments by sheep (from Edmond, 1958 c).

Treatment*	Yield (All species)			
(Stocking-rate equivalent)	28 Aug.	4 Oct.	19 Oct.	1 Nov.
0	355	1890	212	301
4	313	1620	173	266
8	242	1589	124	250
12	193	1174	131	207
16	171	1264	73	192
20	121	1042	73	173
S.E. $\pm$	18	60	7	11
Sig.diff.at 5% level	54	177	31	30

* Pastures were trodden on 31 July, 28 Aug., 4 Oct. and 19 Oct.

Campbell (1966) found that one heavy treading with Jersey dairy cows over 1 or 2 days in the late winter when soil was at field capacity, had little effect on annual dry matter production, nor was there any evidence of cumulative effects when pastures were trodden for 3 years in succession. The highest reduction in any one year at the highest stocking rate was only 7%.

Early work (Davies, 1938; Bates, 1930; Kleckia, 1937) in Europe and the United Kingdom ranked Lolium perenne, Poa annua, Poa pratensis and Trifolium repens to be the most resistant species to treading. In areas of severe treading Poa annua prevailed, and with medium treading Lolium perenne flourished. The success of Poa annua may not be due to any great ability to resist treading; Poa annua is not normally recognised as a strongly competitive species (Younger, 1959), but has a remarkable capacity for regenerating from seed, which would allow it to dominate in the absence of other species under heavy treading. In New Zealand, Levy (1926) reported the use of treading in the North Island hill country, by cattle, to combat susceptible weeds and secondary growth. Edmond (1964) showed differences in species susceptibility to treading of 10 different species; dry matter production was reduced in all species, at all stocking rates, but the order of ranking with regard to resistance to treading changed with the stocking rate used. Lolium perenne and Poa pratensis were the most resistant at the highest stocking rate employed. In a mixed pasture, treading caused an increase in the proportion of Lolium perenne in the sward (Edmond, 1966).

Edmond (1958 a) observed that the immediate effects of direct injury to plants, such as displacement, burial, bruising and destruction, must be distinguished from the persistent effects of altered botanical composition and changed soil conditions. There has however been no precise definition of a plant's reaction to animal treading (Edmond, 1966). Bates (1935) talked of the elimination of those species not adapted to the rigours of treading, of the leaf section offered for treading and the site of the growing point. The physical strength of the leaf (Evans, 1967) and the ability to assume a rhizomatous type growth (Mitchell, 1960) have been advanced as the explanation for the insensitivity of Lolium perenne to treading (Edmond, 1966).

Edmond (1958 c) showed a marked reduction in tiller density following treading, but observed that recovery and reappearance of damaged and buried tillers was rapid. New tillers were initiated over the recovery period to replace those destroyed. Variation in tiller numbers in a pasture were greater between years, than that caused by treading treatments within years (Campbell, 1966). Lower herbage yeilds in heavily trodden plots could be attributed to lower pasture density (Edmond, 1958 c; 1964; 1966) and to the lower growth rate of the new tillers than of those they replaced (Langer, 1957). This is supported by Dutch work (van der Schaaf, 1965) where herbage from poached plots was at a younger stage of growth than that from unpoached plots. A close correlation was also found between herbage yield and the percentage ground cover in early spring. Edmond (1964) noted that reduction in tiller vigour appears to be less over the season of maximum growth of a species.

The indirect effects of treading will operate through changes in soil characteristics; both physical and chemical. Two components are involved, compaction and puddling. Puddling as defined by Bodmin and Rubin (1948) is the process of working clay, loam etc., with water to render it compact, or impervious to liquids. The two processes are therefore related, but at either extreme one can occur in the absence of the other (Lull, 1959; Gradwell, 1956). Compaction in unsaturated soil conditions involves a decrease in the volume of soil air, which is normally accompanied by some destruction of existing clods and is promoted by wetting (O'Connor 1956). Aggregate destruction may be most serious under very wet and very dry conditions, although compaction will be most severe at some intermediate moisture content (O'Connor, 1956). The soils' ability to withstand loads varies according to texture, porosity and moisture. For soils of any one texture and density, the supporting capacity will fluctuate with moisture content (Lull, 1959).

Edmond (1958 c; 1963) has shown a significant trend towards increased bulk densities with increased treading rates. Estimates of the depth to which soil is compacted vary for cattle from the top inch (Alderfer and Robinson, 1947) to the 1" – 5" layer (Robinson and Alderfer, 1952). O'Connor (1956) limits cattle compaction to the top 3" while Edmond (1958 c) limits that of sheep to the top $2\frac{1}{2}$" of soil.

Plant responses have not been related quantitatively to soil compaction, but to specific soil physical phenomena that

arise as the result of soil compaction (Rosenberg, 1964).
Compaction will affect the soil productivity by increased
mechanical resistance to root penetration (Gill and Miller
1956; Veihmeyer and Hendrickson, 1948; Forristall and
Gessel, 1955), reduced aeration (Wiersma, 1959), altered
heat flux (Rosenberg, 1964) and altered moisture availability
(Gradwell, 1966; Lull, 1959; Baver, 1938; Edmond, 1958 c; 1958 d).
Runoff will increase and infiltration will decrease (Alderfer
and Robinson, 1947; Lull, 1959). Gradwell (1966) found that
with treading in wet conditions which had caused puddling,
higher density was associated with a lesser ability for the
soil to store water in the readily available moisture range. At
any point in time one or more of these factors may become
critical to plant growth. Whether these changes are beneficial
to plant growth will depend upon whether the soil is looser than,
at, or more compact than, the optimal density for the season and
stage of growth of the plant (Rosenberg, 1964). Levels of
compaction obtained under pastures in New Zealand (Edmond, 1958 c)
appear insufficient to restrict root growth simply through
increased mechanical resistance. Reduction in aeration has
been shown to reduce the ability of roots to enlarge under
increased mechanical restraint (Gill and Miller, 1956).
Evidence of reduced aeration is seen in the gleying of soils
under heavy treading treatments (Edmond, 1958 c; 1964). Compaction
of Taupo pumice, resulted in a reduction in macro-porosity and
the increase in moisture storage was shown by Packard (1957) to
be beneficial to plant growth.

Species differences have been observed in their reaction
to compaction (Forristal and Gessel, 1955) and in their ability
to withstand lack of soil air and high water tables (Baumann
and Klaus, 1955).

Soils compacted, at or near saturation, will have a small
shift in bulk density, but a large effect upon the soil air voids
(Gradwell, 1956). In the extreme true puddling without compaction
will occur. In puddled soils the situation described will be
intensified, in that the diffusion of gases and water may be
severely restricted by the formation of surface crusts (Domby
and Kohnke, 1956). These workers point out however, that unless
this surface is completely impervious, the rate of diffusion
through a soil does not depend solely on the properties of this
layer.

Plant responses to changes in soil moisture levels will
be reflected through compaction and puddling of the soil and
also through the increased displacement and burial of plants.
In wet conditions direct root damage, plant displacement and
burial in mud appeared to be more extensive than crushing and
bruising of leaves and stems (Edmond, 1963). Reduction in yield
was significantly increased with increased soil moisture (Edmond,
1963). Scott (1963) showed that losses due to treading in the
winter could be reduced by drainage.

Soils with high organic matter content (O'Connor, 1956),
fertility (Edmond, 1966), or good soil structure (Edmond, 1962 ;
Lull, 1959), will have a low bulk density and can be greatly
deformed or compacted. Organic matter, as a surface mat will

impart considerable bearing strength to the soil (Lull, 1959; O'Connor, 1956); vegetation cover can also act in a similar manner (Clement and Williams, 1958; O'Connor, 1956; Brown, 1968) and reduce dry matter losses from treading.

Few estimates have been made of the recovery of soils from compaction and puddling. Recovery will depend upon the type of plant and its rate of root growth (Lull, 1959). Root growth in compacted layers is promoted with adequate fertility and P and Ca appear to be of major importance (Wiersma, 1959).

Soil organisms must play a role in the recovery of soils, but have been largely neglected in this respect in the literature. Earthworms showed a variation in population with plant yield (Edmond, 1962; 1963), there being fewer present in heavily trodden plots. Recovery will also depend upon the degree of shrinking and swelling of the soil caused by variations in water content and temperature (Lull, 1959). Gradwell (1966) found that the effects of puddling in wet winter conditions on soil moisture deficiency had largely disappeared after six months and had completely disappeared after ten months.

1.3.3 Excretion

Dung and urine excreted by the grazing animal has an impact on both pasture and soil. Sears, Goodall and Newbold (1948) showed that 33% yield increases could be obtained by the return of dung and urine as compared with their non-return. Urine alone produced 15% increases and dung alone 18%. Similar experiments carried out at different localities in

New Zealand and the United Kingdom did not always show the
same results (Herriott and Wells, 1963; Sears and Thurston,
1953; Watkin, 1954; Wheeler, 1958; Wolton, 1963) as animal
returns only appeared to promote production increases under
reasonably high fertility conditions. Excreta return will
depend upon individual animal characteristics, such as, the
rate at which excreta are produced, the area covered by a
single excretion and the nutrient content within each excretion.
In terms of the grazed pasture these individual factors will
combine with the length of the grazing period and stocking
rate, to give the total area affected by excreta over any
given period. The persistency of the effects from a single
excretion will depend upon its affect on pasture growth,
death, and availability, and the rate at which returned
fertilizer elements are lost from the soil.

Most observational trials show cattle to defaecate
11 - 12 times (Hancock, 1950; Goodall, 1951; MacLusky, 1960)
and urinate 8 - 11 times (Hancock, 1950; Goodall, 1951;
Petersen, Lucas and Woodhouse, 1956 a) daily, with individual
excretions covering slightly less than 1 ft^2 (Petersen et al.,
1956 a; MacLusky, 1960; MacDiarmid, 1969) and 3 - 4 ft^2
(Petersen et al., 1956 a; Doak, 1952) respectively. Goodall
(1951) found 40 lb (wet matter) of dung excreted per animal per
day, with individual excretions ranging from 1 - 15 lb.
Urinations varied from 850 - 2,850 ml. with a mean volume of
1600 ml (Doak, 1952) and a duration of from 5 - 10 seconds
(Goodall, 1951). Little variation was apparent between breeds
(Doak, 1952).

The distribution of excreta throughout the day is of
importance if stock are grazed on more than one area, or are
to be removed from pasture for a major portion of any 24 hour
period. Hancock (1953) observed that dairy cattle grazed and
excreted at a ratio of 60 : 40 for the day and night intervals
between milkings; so he concluded that if areas to be grazed
for the two periods varied in size according to this 60 : 40
ratio for day and night respectively, no fertility transfer would
be taking place. This contention was not supported by experiments
at Alberystwyth (Goodall, 1951) and Palmerston North (Sears, 1953).
Goodall (1951) showed that when the weight of dung voided rather
than numbers of defaecations was studied, excretions at night
were heavier than those passed during the day and concluded that
on average 72% of dung was returned to the day paddock compared
to intake over this period; while at night the return was 115%

The grazing animal removes only a small quantity of nutrients
from the pasture (Table II), the remainder being excreted in dung
and urine. (Davies, Hogg and Hopewell, 1962).

TABLE II : Fate of nutrients ingested by dairy cattle
(from Davies et al., 1962)

	Dung (%)	Urine (%)	Milk (%)
Mg	80	10 – 12	5
Ca	75	4	10
K	10	80	5
P	62	–	25

About 75% of nitrogen (N) is excreted (Petersen et al.,
1956 b) and of this 70 - 75% is voided in the urine (Doak, 1952).
For a dry animal proportionately more nutrients, especially
phosphorus (P) will be returned. Where pastures vary markedly
in composition and quality between seasons, changes in the
concentration of nutrients in excreta (Barrow and Lambourne,
1962 ; During and McNaught, 1961) and in the distribution of
nutrients between dung and urine (Barrow and Lambourne, 1962)
will occur. Barrow and Lambourne (1962) found that for Merino
wethers faecal excretion of N and S per unit of feed eaten was
not significantly affected by the N and S content of the feed
eaten, nor by the level of feed intake. The remainder of the
N and S was excreted in the urine and hence the proportion
excreted in the urine will depend on the N and S content of the
feed. For example, when N in the feed was high, 80% of excreted
N was in the urine, and when N in the feed was low as little as
43% of excreted N was found in the urine. S varied in the urine
from 90% to 6% of that excreted. Pasture quality and seasonal
changes in New Zealand are unlikely to vary to the same extent
as those encountered in Australia by Barrow and Lambourne (1962)
and therefore the concentration and proportion of these nutrients
in the urine will be much more stable under New Zealand conditions.

Excreta is potentially a significant source of nutrients
for a pasture, the extent of which will be largely dependent on
the nutrient intake of the grazing animal. Watkin (1954) found
that with low herbage production the return of excreta had little
or no effect, but in association with high N treatments, and
consequently high herbage yields, faecal returns appeared to

contribute to productivity.

Dung and urine contain a large number of elements, of which N, S, P, K, Mg and Ca are the most important, though most of the micronutrients are also present (Dale, 1963). The nutrient potential can be visualised, when for example, it has been calculated by Davies et al. (1962) that the annual output per cow of P and Mg in dung is equivalent to 190 lb superphosphate and 180 lb magnesium sulphate respectively. Due to the discrete nature of individual excretions, the concentration of nutrients under dung and urine patches can be high (Table III). Figures quoted for excretal nutrient return have little absolute meaning but they serve to illustrate the considerable concentration of nutrient which can be deposited over an area of $1 - 3$ ft^2 of the pasture. If the grazing animal is offered large quantities of nutrients in its feed supply, the bulk of this will find its way back to the pasture via excreta.

TABLE III : Concentration of nutrients (lb/acre) under individual excretions (calculated by Petersen et al., 1956 b).

	Dung	Urine
N	760	400
P_2O_5	350	15
K_2O	440	420

For every new excretion added, all things being equal, one old excretion will be losing significance. A time period can be visualised, dependent on the loss rate of the nutrient from the excreta and its effect on the environment, after which any added excreta will not increase the area and amount of active nutrient return. This situation has been defined as the 'steady state' with respect to nutrient returns (Petersen et al., 1956 b) and to pasture rejection (MacLusky, 1960). The level of nutrient return will depend upon the quantity of excreta deposited over this period, which will be predominantly a function of stocking rate. The time period will be relatively constant irrespective of stocking rate. Petersen et al (1956 b) quote data in evidence that the loss of nutrient (in this case N and K) is proportional to their concentration in the soil. At the loss rate and nutrient levels used, at one beast per acre, it was concluded that when a 'steady state' was reached for N only 16% of the pasture was covered, while for K a large area (37%) was covered owing to the slower loss rate of this element.

Differing areas covered, nutrient levels and persistency means that dung and urine should be regarded separately.

(i)   Urine

The major elements present in urine are N and K (During and McNaught, 1961). Yield responses to urine persist only for 2 - 3 months and are often attributed to the initial N response of the grasses followed by competition depressing the clovers (During and McNaught, 1961; Lotero, Woodhouse and Petersen, 1966). The area affected by urine varies with the moisture

status of the soil (Dale, 1961; Doak, 1952), slope (Dale, 1961),
soil type and texture (Doak, 1952). It was found by Herriott
and Wells (1963) that the response extended 2" from the edge of
a urine patch; this means in effect that the estimated 432 lb
urine - N per acre over 45 in^2 in their experiment would fall
to 194 lb per acre on the basis of 100 in^2.

Excreta return experiments have shown relatively low
recoveries of N and K, from urine, by the pasture (During and
McNaught, 1961). N recovery was probably under-estimated because
of the higher clover content in the non-return treatment.
Measurable increases in exchangeable K still existed after two
years (Lotero et al., 1966; Davies et al., 1962).

Within a given environment, the magnitude of effect and
rate of decrease in effect appeared to be due to the rate of
plant growth, while the loss rate appeared to be a function of
both growth rate of the pasture and the amount of nutrient
present (Lotero et al., 1966). Urine has been shown to have
depressing effects on the levels of other nutrients, (P, Mg
and Ca) in the soil and herbage, caused by pasture demands for
growth, differing botanical composition and the balance of ions
(Watkin, 1957).

(ii) Dung

The majority of Ca, Mg and P is returned in the dung as
well as appreciable quantities of N and K (Petersen et al.,
1956 b; Davies et al., 1962). It appears that the P in dung
is in a very stable form and is of little immediate value to
the pasture (Watkin, 1957). The low water solubility of faecal

inorganic P means its value for grass depends on the extent of
dung/root contact (Gunary, 1958). If incorporated in the soil
this inorganic P appears to be as available as P applied as
superphosphate (Gunary, 1958). Availability of P is therefore
probably enhanced by biological breakdown and incorporation of
dung in the soil. All faecal K and 62% of Mg was found to be
soluble in water (Doak, 1952). The N and K appear to be the
most mobile of all nutrients present in dung (MacDiarmid, 1969).
Dung will also improve the organic matter content of the soil
(Melville and Sears, 1953).

Weeda (1967) found that the growth response of pasture to
dung was generally small and this response was at its lowest in
the autumn. This slight initial response was followed by another
period of somewhat increased growth after the final and rapid
decomposition of the dung. MacDiarmid (1969) recorded a 30%
increase in D.M. in the 6" surrounding a dung pat. There was
a suggestion that the grass response was primarily due to the
K and N compounds mobilized from the dung. Over a two month
period (December – January) the area covered by a dung patch
showed a 30% depression in D.M. yield if the patch was left on
the pasture for more than 6 days and a 70% depression if remaining
for 15 days (MacDiarmid, 1969).

Very liquid dung had little affect on the botanical
composition (Weeda, 1967), but if the dung remained in place for
longer than 15 days plants beneath the deposit are killed
(MacDiarmid, 1969). The periphery of bare patches left were
usually covered fairly rapidly, mainly by tillers from

surrounding grasses, while the central area often remained sparsely covered for 6 to 12 months (Weeda, 1967).

Urine spots appear to have little affect upon the behaviour of the grazing animal. Norman and Green (1958) observed that urine spots were avoided at the first grazing following their deposition. MacLusky (1960), found urine to increase the palatability of pasture and the herbage on urine patches to be readily consumed. The rejection of herbage around dung patches however is of greater significance and has been studied by several workers (MacDiarmid, 1969; Martin and Donker, 1964; Norman and Green, 1958; Taylor and Rudman, 1966; Weeda, 1967).

MacDiarmid (1969) gives four phases in the grazing behaviour of dairy cattle:

i.   Tops are grazed irrespective of dung.

ii. Intensive grazing between dung sites with selection also apparent within this region.

iii. Dung sites are grazed.

iv. Cows appear to be restless and hungry, but prefer to return to the severely grazed between-dung site area rather than completely defoliate around the dung.

If this behaviour is normal, then the extent of pasture rejection will be a function of stocking rate and the length of the grazing period. Initial neglect of herbage around animal droppings is due to the dung itself (Norman and Green, 1958;

Martin and Donker, 1964) but the resultant ungrazed herbage then becomes mature and unpalatable, and subsequent refusal due to lack of palatability of herbage rather than the proximity of dung (Norman and Green, 1958). It is probable that odour plays a large part in the initial rejection of dung sites (Martin and Donker, 1964) but this rejection will be largely overcome if choice is restricted (Tribe, 1949). The major source of wastage is not rejection around dung pats from previous grazings but rejection surrounding faeces voided on ungrazed pasture (MacLusky, 1960; Weeda, 1967). Rejection periods of from 2 - 3 months (Weeda, 1967) to 13 - 18 months (Norman and Green, 1958) have been observed. An important feature in rejection and pasture ecology is the length of survival of the dung pat. The 'life' of the pat was found to vary with season, disappearing in 1 - 2 months in the autumn and 4 - 6 months in the late spring and summer; extremes of from 2 weeks to 17 months existed (Weeda, 1967). Weeda (1967) found two factors important, whether or not a hard crust was formed and the initial consistency of the dung. If a crust was formed, the initial consistency was irrelevant. The margins usually decomposed first, the central area decomposed rather slowly from the underside upward until the patch was broken into a number of pieces, after which disappearance was rapid. Harrowing depressed pasture growth 15% over a 3 year period, but promoted more even grazing (Weeda, 1967). Macro and micro-organism activity within dung pats will also aid disintegration (Laurence, 1954; Waters, 1955; Barley, 1959). Increased earthworm numbers and weights were

found in those plots receiving dung return (Watkin and Wheeler, 1966).

The variable over which management has most control is stocking rate, it is this that determines the area covered by the 'steady state' and the extent and duration of rejection of the sward around dung pats by the grazing animal.

1.4.1 Winter Pasture Production

Aspects of pasture regrowth following defoliation have been discussed in Section 1. 2 and the modification of these responses with the introduction of the grazing animal are dealt with in Section 1.3.1. This section deals more specifically with what pasture production levels can be obtained over the winter period (June - August) in particular at Palmerston North.

At Palmerston North during the winter, prevailing weather conditions (Appendix 1) are very seldom severe enough to stop grass growth, although temperatures and the amount of incident light energy available are low enough to limit growth (Brougham, 1960 b). As shown by Mitchell (1956) 'English' grasses show little variation in growth rate between 55° and 85°F; lower temperatures will limit growth, with light having effect within temperature movement. Thus effects of periods of low light intensity are somewhat lessened as these periods often are also subject to temperature restrictions. Daily dry matter (D.M.) increments of 15 - 29 lb per acre have been recorded at Palmerston North (Brougham, 1956 b). The amount of foliage required to

intercept and utilize all light over the winter period is small (Brougham, 1958), probably in the vicinity of half that required in mid-summer. This would give 95% light interception at LAI of 3.6 and 1.8 by perennial ryegrass and white clover respectively (Brougham, 1958).

Production over the winter period will be markedly influenced by previous management in the late summer and autumn, as this will determine the botanical composition of the pasture and therefore the limit of its winter growth potential. In New Zealand grasses usually dominate during the late autumn, winter, and early spring because of their better tolerance of the temperatures that occur at these times (Mitchell, 1956). Recovery in later seasons, of pastures leniently grazed in the summer is often poor as pastures are unable to exploit temperatures favourable for ryegrass growth in the late autumn owing to the summer clover dominance and ryegrass death (Brougham, 1966). Yields obtained from intensive grazing in the autumn are lower than for similar pasture more leniently treated; but the intensive autumn grazing allows the ryegrass component to recover (Brougham, 1960). Any autumn management system that promotes the grass component will aid winter production. The necessity for tiller production in the autumn has been previously mentioned. Periodic close grazing may stimulate tillering in Manawa ryegrass by preventing basal shading (Mitchell and Coles, 1955), but persistant close grazing may have the opposite effect with this and other species (Brougham, 1959). Campbell (1961) considers close grazing is perhaps inevitable toward the end of the summer

period and that this will be sufficient to stimulate the
desirable degree of autumn tillering.

For a given pasture, growth over the winter period will
be influenced by two main factors, the quantity of herbage
required to intercept all incident light (Brougham, 1958) and
the rate of decomposition within this pasture over the late
autumn and winter (Brougham, 1966). As the last autumn
defoliation was delayed into the winter, the time required before
the pasture was able to intercept 95% incident light increased,
the maximum growth rate was reduced as was the maximum yield
obtained (Table IV) (Brougham, 1956).

TABLE IV : The growth of Manawa ryegrass pastures in the late
autumn and winter (from Brougham, 1956 b).

	Date of last 'Autumn' defoliation			
	1st April	22nd April	13th May	3rd June
Max. growth rate (lb D.M. per day)	57.5	40.0	40.5	– *
Time to max. growth rate (weeks)	4.5	5.5	4.6	–
Yield when max. growth rate (lb D.M. per acre)	1060	789	679	–
Max.yield (lb D.M. per acre)	2120	1577	1357	–
Yield on 5th August (lb D.M.per acre)	2007	1825	1478	1268

* Treatment 4 did not reach maximum growth rate after 9 weeks.

If large areas of pasture are spelled for lengthy periods
in an endeavour to carry autumn saved pasture (ASP) through the
winter for utilization by the herd after calving, losses through
decomposition can be high (Table V) (Brougham, 1956 b). The
first closing date (April 1) used by Brougham (1956 b) in
Table IV and upon which Table V is based, is somewhat earlier
than those used on most dairy farms as will be shown in Section
1.4.3. This probably over-emphasises the losses experienced by
one 18 week spell as compared with three six week spells.

TABLE V : Growth of Manawa ryegrass pastures in the winter
under three defoliation treatments (from Brougham
1956 b).

Treatment	Average growth rate (lb D.M./acre/day)	Total yield lb D.M./acre
One 18 week spell	17	2120
Two 9 week spells	26	3290
Three 6 week spells	29	3620

Pasture production is, therefore, favoured by frequent
heavy grazings (Brougham, 1959). Excessive spelling over the
winter period will cause death of the clover component and is
thought to result in low soil -N in the early spring, poor rates
of photosynthesis and lowered early spring production (Brougham,
1966). Sears (1962) considers that laxly grazing pastures over

the winter will increase the content of what he terms the less desirable grasses in the sward (e.g. Poa trivialis and Yorkshire fog). Poa trivialis has also been shown to invade pastures heavily grazed over the winter (Watkin pers.comm.)

1.4.2 Animal requirements

To achieve the objectives of winter management, it is necessary to have a knowledge of the maintenance requirements of the cow, the requirements of the unborn calf and the requirements for liveweight gain.

1.4.2.1 Maintenance requirements

Overseas values (Nat. Res. Council, 1966; Ag. Res. Council, 1965) for maintenance, provide minimal energy requirement to cover usual activity of cows fed in confinement, but not for grazing. These values relate to stall fed animals held indoors. Extrapolation of these data to the freely grazing animal was made by incorporating loadings for walking, standing, grazing, ruminating and possibly environmental exposure. The extension of indoor observations to the grazing animal has, to quote McDonald (1968), "presented truly formidable obstacles". He points out that there is no reason to believe that there is any difference in the fundamental biology of animals in the two environments, and it is rather in the quantitive aspects that the major differences are observed. Levels and composition of intake will differ as will environmental conditions and animal behaviour. Graham (1964) calculated the maintenance requirements of grazing animals to be

from 16% to 72% above those of animals in calorimetry studies. The actual amount is dependent on the 'work' required by the animal to obtain a maintenance intake from the pasture on offer. He gives a figure of about 30% for the increase in maintenance requirement for grazing good pasture on a level paddock. Blaxter (1962; 1964) puts the figure at 20%.

Maintenance values have also been calculated directly using the grazing animal. The accurate measurement of the intake of the grazing animal is the great difficulty with this method. Indicator methods are normally used and these have often been the subject of criticism for inherent errors (Raymond, 1966; Moule, 1964; Langlands, 1967; 1969). With this method high levels for maintenance have been obtained (Coop and Hill, 1962; Wallace, 1956; Lambourne and Reardon, 1963).

Wallace (1965) using regression analysis found the following relationship for lactating Jersey cows :

$$DOM = 0.35 \text{ f.c.m.} + 0.08 \text{ L.W.}^{0.73} + 3 \text{ L.W.G.}$$

where :

DOM = Digestible organic matter intake
        per day (lbs)

f.c.m. = Fat corrected milk (lbs)

L.W. = Liveweight (lbs)

L.W.G. = Daily liveweight gain (lb)

This value for maintenance of 0.08 L.W.$^{0.73}$ is considerably in excess (66 - 78%) of those quoted from overseas (Table VI). Work at Ruakura was extended to the feeding of

pasture indoors (Hutton, 1962; Wallace, 1961). When dry
cattle were kept to a constant weight, the maintenance
requirements were similar to overseas values; when pasture
was fed to appetite, for a 1000 lb cow maintenance requirements
increased by 45% when dry and 98% when lactating (Hutton 1962).
In addition to the increase in maintenance associated with
grazing, Hutton (1962) has now also shown that maintenance
requirements can vary considerably indoors when animals are fed
pasture at varying levels.

Lambourne and Reardon (1963) observed that the maintenance
requirement varied with grazing pressure. When liveweights were
maintained by regulating grazing time rather than stocking rate
the increase in maintenance requirements was approximately
halved. These changes were thought to be associated with an
increased energy 'cost' of harvesting and what the authors
termed stress factors. Coop and Drew (1963) confirmed this
effect of pasture availability on maintenance requirement.
Young and Corbett (1968) however with sheep maintained at weights
similar to those of Lambourne and Reardon (1963) did not find
this relationship, they found maintenance to be proportional to
liveweight.

Table VI shows examples of the maintenance requirements
of a 750 lb and 1,000 lb dairy cows calculated from overseas
and New Zealand sources. Given a pasture with an average DOM
content of 70%, the DM intake to meet maintenance demands as
shown in Table VI vary for a 750 lb cow from 8.07 to 16.89 DM
per cow per day. Only the figure of Wallace (1956) allows for
grazing or an outdoor environment.

TABLE VI : <u>Maintenance requirements for dairy cattle (lb DOM and lb D.M. per cow per day.)</u>

Source	Wt (lb)$^{0.73}$	750 lb cow			1000 lb cow		
		DOM	DM*$_1$	DM$_2$	DOM	DM$_1$	DM$_2$
Nat. Res. Council[+]	0.043[++]	5.45	9.08	7.79	6.67	11.12	9.53
Ag. Res. Council	0.048	6.02	10.03	8.6	7.44	12.40	10.63
Wallace (1956)	0.08	10.04	16.73	14.34	12.39	20.65	17.7
Wallace (1961)	0.063	7.91	13.18	11.3	9.76	16.27	13.94
Hutton (1962) a	0.048	6.02	10.0	8.6	7.44	12.4	10.63
b	0.07	8.79	14.65	12.56	10.84	18.07	15.49
c	0.095	11.82	19.7	16.89	14.71	24.52	21.01

* DM requirement calculated for DOM content in pasture at 60% (DM$_1$) and 70% (DM$_2$).

+ Overseas values published in lb TDN (Nat.Res.Council,1966) and kcal Metabolizable energy (kcal ME) (Ag.Res.Council, 1965) Conversion factors used were :

1 lb TDN = 1620 kcal ME (Nat.Res. Council, 1966)
1 lb TDN = 1.04 lb DOM (value for pasture given by Wallace 1961).

++ Calculated from maintenance figures given for 450 kg (Nat.Res.Council, 1966) and 400 kg (Ag. Res. Council, 1965) cows.

a Maintenance figures for dry cattle at constant weight
b Maintenance figures for dry cattle fed to appetite
c Maintenance figures for lactating cattle fed to appetite

1.4.2.2 Pregnancy

It was concluded by the Ag. Res. Council (1965) from the work of Van Es (1961) and Brody (1945) that heat production increases in late pregnancy at a rate which is greater than from a non-pregnant animal retaining the same amount of energy. They assume this increase is due to increased liveweight and increased maternal maintenance costs. The actual reproductive liveweight gain for practical purposes should be taken to be 1200 kcal ME per day in the penultimate month of pregnancy rising to 2400 kcal ME per day in the last month (Ag. Res. Council, 1965). Also in the last month of pregnancy the fasting metabolism should be increased by 20% (Ag. Res. Council 1965), to account for the increase in maintenance already mentioned.

If basal metabolism for dairy cattle is taken as 80 kcal per kg $^{0.73}$ (Forbes, 1926) then requirements for pregnancy will involve a 20% increase in this figure and an allowance for weight gain due to pregnancy (Table VII).

TABLE VII : Estimated daily energy requirements for pregnancy (lb DOM and lb DM).

	750 lb Cow			1000 lb Cow		
	DOM	DM_1**	DM_2	DOM	DM_1	DM_2
Basal metabolism*	3.35			4.13		
Basal metabolism + 20%	4.02			4.96		
Energy retained						
a. second last month	0.74			0.74		
b. last month	1.48			1.48		
Increase due to pregnancy						
a. second last month	1.41	2.35	2.01	1.57	2.62	2.24
b. Last month	2.15	3.58	3.07	2.31	3.85	3.30

* Basal metabolism equals 80 kcal/kg $^{0.73}$(Forbes, 1926)

** DM requirements are calculated for DOM content in the feed of 60% (DM_1) and 70% (DM_2).

\+ Conversion factors are the same as shown beneath Table VI.

1.4.2.3 Liveweight gain

Work at Ruakura (Hutton, 1962; Wallace, 1956; 1961) has given values ranging from 1.64 lb DOM to 3.0 lb DOM as the intake necessary for 1 lb liveweight gain. The efficiency of conversion of ME to liveweight gain is least in mature animals and in non-lactating animals (Blaxter, 1962) and therefore it seems reasonable to use Hutton's (1962) figure of 2.92 (approximately 3.0) lb DOM/lb weight gain. As a DM requirement this would be 4.28 lb and 4.17 lb per lb weight gain for pasture of 60% and 70% DOM content respectively.

1.4.2.4 Requirement of a dry cattle beast

Daily maintenance requirements are uncertain, the best that can be done is to accept published values (indoors) and add 30% for grazing. This 30% grazing allowance may be adequate on average but at times appears to be totally inadequate.

For early winter grazing when cows are maintained at roughly constant liveweights, overseas stall feeding values are similar to those obtained in New Zealand (Hutton, 1962). Hutton's estimate for maintenance (0.048 L.W.$^{0.73}$(lb)) plus 30% for grazing gives a requirement of 10.63 lb DM and 13.83 lb DM for a 750 lb and 1,000 lb cow respectively. When fed to appetite the corresponding requirements would be 16.34 and 20.0 lb DM.

Requirements for pregnancy and growth will presumably be similar out-of-doors as those in a more controlled environment for similar foodstuffs and as a consequence indoor results can be used directly.

1.4.3 Winter Management

This section is included in the literature review as an attempt to show how the New Zealand dairy farmer is wintering his stock. Some methods are based on a sound agronomic basis as outlined in early sections of this chapter; some are not. Experimental literature on the overall picture is scarce and most systems have been derived as the result of observation and farmer innovation. Comments and discussion are from the personal observations of the author and from published reviews rather than from experimental results. It is attempted to discuss the evolution of winter grazing practices in recent years, but it should be borne in mind that any system is not rigid and that individual variation in approach will naturally exist, as will differences in winter growth, stocking rates and managerial ability between farms and farmers.

The objectives of a wintering system must be orientated around the requirement of calving the herd at such a weight and in such a condition that production over the subsequent lactation is enhanced. On the one hand there is this desire to adequately feed the animal before calving and on the other the need to provide as much pasture as possible for the post calving needs of the animal.

Three animal requirements influence decisions on wintering
the requirements of the cow in late lactation, over the dry
period and after calving. The variables manipulated by the
manager are the time of drying off, the time of calving and
the stocking rate.

Pasture production levels over the winter in the major
dairying regions of New Zealand are in general sufficient to
adequately carry one dry dairy cow per acre. The management
problem is brought about by the sudden increase in pasture
requirement that occurs following calving and the natural desire
to utilize the minimum quantity of feed resources while the cow
is unproductive.

Trials at Ruakura (Lees, McMeekan and Wallace, 1948) and
Palmerston North (Flux, 1950) showed severe underfeeding prior
to calving produced a fall in butterfat production of 50 - 60 lb
per cow over the following lactation. Less severe restrictions
in feeding levels over the winter period have little effect on
subsequent animal production (Wallace, 1958; Campbell and Clayton,
1966).

Stocking rates on New Zealand farms up until the last
decade, were such that utilization by the herd was low over the
spring, consequently large areas of hay and silage were
conserved annually. The standard recommendation for wintering
called for the conservation of $\frac{1}{3}$ acre per cow as hay or silage
and a similar area of ASP (Campbell and Clayton, 1966). As
stocking rates increase however, there comes a point where the
need to conserve large levels of hay and silage is in conflict

with the herd's requirement over this period. Conservation,
though widely practised is biologically inefficient, large
losses being associated with the conservation of the hay or
silage and with its subsequent utilization (Wheeler, 1968).
It is desirable, therefore, to feed as much as possible of the
pasture directly to the grazing animal in situ. Lowered
supplies of hay and silage necessitate a greater dependence on
grass as a feedstuff for both wintering and early lactation.
This requirement, has led to cows being calved later, nearer
the onset of spring growth. The move to later calving being
accelerated by increased stocking rates. At the same stocking
rate wintering becomes easier and more flexible with a late
than with an early calving date (Hutton, 1968). Brougham (1966)
showed that frequent grazings produced maximum yields over the
winter period, but in practice a farmer may prefer to grow less
but have this lowered quantity when it is most wanted (viz. after
calving).

The saving of ASP has been recommended for use immediately
before and after calving (Wallace, 1958); a recommendation that
cannot be equated with late calving up to four or more months
after the bulk of autumn growth is obtained. ASP has more
recently been used as a winter supplement in such a way that
one heavy grazing is followed by a 70 - 90 day spell, the regrowth
being used following calving. The conflict now arises between the
use of autumn growth as ASP for wintering or as fodder for the
milking herd in late lactation. Hutton (1962) reports the
improvement in feed quality in March and April, is reflected by

increased intake by the milking cow, reaching 90% of the maximum intake obtained in late spring. The comparable figure for milk yield is only 60% and he notes the unnecessarily wasteful utilization of high quality feed which can occur in the autumn. A greater dependence on pasture for wintering means the time of drying off is less flexible (Bryant, 1969) and the management decisions made at this time become more critical (Hutton, 1968).

Associated with winter grazing will be degrees of pugging, poaching and fouling of pastures. This factor has probably in the past influenced thinking on wintering to a greater extent than has pasture utilization and growth. These effects were thought to be a major drawback to higher production in the early 1950 s, so in an attempt to obtain high production at 1 cow/acre the 'sacrifice' paddock wintering system was developed (Riddet, 1954). The idea was to restrict damage to one area (usually 1 paddock) of the farm. Cows were allowed sufficient grass during the day for estimated requirements and then returned to the 'sacrifice' area. It was necessary to feed supplements early in the winter (Stewart, 1954) and to plough the sacrifice area following wintering; which meant spring sowing of pastures or a summer crop. In recent times the use of on/off grazing associated with wintering pads and barns is a more logical extension of this system with the 'sacrifice' having been removed.

Another method was to set stock the herd for the duration of the winter over approximately one half the farm at a

stocking intensity of probably 2 cows/acre (McKenzie, 1960).
Kirton (1962) considered that regrowth from these set stocked
areas would be greater than if mob stocked, because of less
poaching and treading damage; a contention not supported by
Edmond (1965). The system is a negative approach to wintering;
its main objective being the reduction of pasture damage
associated with grazing, and it is not altogether certain that
this is achieved. It is not ideal for the animal, in that cows
start the winter on a high plane of nutrition and after this
initial period are on a decreasing plane. The main disadvantage
is the calving of the herd with half the farm devoid of pasture
and facing a slow regrowth. Hutton (1966) showed the problems
in the system when attempting to use it when stocked at $1\frac{1}{2}$ cows
per acre. Set stocking is a luxury of low stocking rates and
some form of control must be introduced. Campbell (1966) obtained
increased pasture utilisation and growth when winter grazing was
controlled rather than set stocked.

Set stocking as practised at No. 3 Dairy, Massey University,
has gradually evolved into a block grazing system. At first the
move was toward break feeding the set stocked groups over their
paddocks with no back fence, until at present only 1 or 2 groups
are break grazed, at stocking intensities of greater than 200
cows/acre with both a front and back fence being shifted daily.
This development followed what had already taken place on many
heavily stocked commercial dairy farms. Block grazing, restricts
the dry herd to a small area of the farm each day. Stocking
intensities are high and on days that treading damage does occur,

the damage is likely to be severe; but weighed against the whole farm, the area affected is small. The damage may be agronomically disasterous for this area, but sound practice for the whole farm.

Reports of successful wintering on farms carrying two milking cows per acre have been made by Smith (1968) and Hutton (1968). At Waimate West (Smith, 1968), dry cows are block grazed over the whole of the farm, during the winter period. They are shifted daily and the stocking intensity at the start is about 100 cows/acre, but increased as grass availability increases. About 4 lb. hay/cow/day is fed. At Ruakura (Hutton, 1968) wintering was on grass alone, made available earlier by slowing the grazing rotation of the milkers from April until mid-June, and feeding hay or silage to both milkers and dry cows at this stage. Grazing is rationed throughout the winter at 200 to 300 cow grazing days/acre; resulting in about two thirds of the farm being grazed in a 10 - 12 week rotation. The farm reported at Waimate West was self-sufficient in feed supplies over the year, but at Ruakura upwards of 700 lb meal/acre/year has been purchased.

The use of off-paddock wintering systems has been discussed (Batten, 1965) but the requirement of wintering on pasture means the animals are still grazed. Duration of grazing need only be short however, as a cow can eat large quantities of pasture in a short time (Wallace, 1958). Platforms will be of benefit for the complete removal of stock from pastures at times when damage is likely to occur. This benefit has not been reflected in

increased farm output with stocking rates of up to $1\frac{2}{3}$ cows
per acre at No. 3 Dairy unit, Massey University, but may exist
in areas extremely vulnerable to winter grazing (Batten, 1965).

Complete elimination of conservation practices in the
spring and early summer, while desirable to achieve maximum
butterfat production at these times, will necessitate the
purchase of feed for use in late autumn and early winter (Hutton,
1966). Bryant (1969) discusses various methods of shifting the
conservation period into the autumn, mainly through the use of
high producing crops such as maize and sudan grass hybrids (viz.
Trudan).

Increasing winter production through the use of winter
forage crops or grasses has not been discussed, as in the main
dairying regions of New Zealand they are not grown to any
extent for utilization by non-lactating animals. Winter forage
crops are frequently grown on town supply farms for utilization
by lactating animals. Winter crops are not grown as pasture
growth is obtained throughout the winter and any winter crop
paddock is not producing when feed is at a premium in the early
spring.

The use of nitrogenous fertilizers over the winter period
has become a more widely accepted practice in recent years,
either in May for winter feed or July/August for milking feed.
For N applied at 40–50 lb N/acre it can be expected to produce
about 400 to 500 lb extra DM for each hundredweight applied
(Bryant 1969).

Early fears that high production was limited by winter poaching have been somewhat dispelled by the successful carrying of up to two cows per acre through the winter. This is not to say damage is not taking place, but it is controlled, as is the pasture utilization and growth. The winter problem has been overcome by improved management, but at the stocking rates employed and with the greater reliance upon pasture as a winter feed, the immediate and cumulative effects of mismanagement are greater than with low stocking rates (Hutton, 1968).

C H A P T E R   II

EXPERIMENTAL OUTLINE AND METHODS

2.1   Introduction

The experiments took place in the winter of 1969 on an
area of the No. 3 Dairy Unit, Massey University, Palmerston
North (Lat. $40^{\circ}23$'S, Long. $175^{\circ}37$'E, Altitude 110 ft a.s.l.)

Soil type is classified as Tokamaru Silt Loam; an
alluvial soil with the profile showing a 6" - 8" dark-brownish-
grey heavy silt loam on a mottled clay loam. It normally has
a reasonable P and Ca status but is often low in N and K
(New Zealand Soil Bureau, 1954).

The experimental area covered 4.5 acres all previously run
for several years as part of the 'reserve herd' farm of the
No. 3 Dairy Unit. All paddocks used were tiled and mole drained
by the Massey Drainage Service in November 1964. Mole drains
are effective in this soil type and last for many years, but
even with drainage these soils tend to be wet in the winter
(During, 1967). The area was in either three or four year-old
pasture. Mixtures sown had consisted of 8 lb Manawa ryegrass,
3 lb cocksfoot, 3 lb timothy, and 3 lb white clover, giving a
seeding rate of 17 lb/acre. Pastures received annual dressings
of 3 cwt of superphosphate per acre; in addition 100 lb of
calcium ammonium nitrate per acre was applied in August 1968.
The paddocks used for the two main trials were both cut for a
late hay crop (46 - 54 bales/acre) the summer preceeding the
experiment.

2.2   Experimental Outline

The experiment was designed to provide information on
the effects of intensive winter grazing on the utilization*
and regrowth of pastures. An experiment was run in early winter
(June) and repeated on a new area later in the same winter
(August) in an endeavour to obtain estimates of the effects of
the various treatments when applied to a similar soil type, but
under differing soil conditions and with different environmental
conditions for regrowth. The June and August experiments will
be called Experiment I and Experiment II respectively for the
remainder of the text.

The main variables studied were grazing intensity and
grazing duration. Grazing intensity being defined as the number
of cow grazing days per acre (cow days per acre) and grazing
duration as the length of the grazing period in which the
grazing intensity was achieved.

Treatments studied were two grazing intensities (120)
and 200 cow days per acre) and three grazing durations (6, 24
and 72 hours) all being replicated three times in a 2 x 3 x 3
factorial experiment laid out in a randomized block design. A
control treatment without the grazing animal (involving two
cutting heights) was included, but although replicated three
times it was not included in the basic layout, but used to
occupy small unused areas within each replicate (as shown in
Figures 2 and 4).

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* Utilization as used in this and subsequent chapters
   describes the quantity of herbage consumed by the
   grazing animal with respect to the quality of herbage
   offered.

Grazing durations used need further explanation as the nomenclature used (6, 24 and 72 hours) is not self explanatory as is that used for grazing intensities (120 and 200 cow days per acre). The length of the grazing period associated with each experiment was three days and within stocking intensities the area on offer to the cows was subdivided in three ways : —

i. Cows received all pasture to be offered over the three day period at the start and remained on this area until the end of the period, taking the full three days to reach the desired grazing intensity (72 hour treatment).

ii. Cows received one third of all pasture to be offered over the three day period at the start and then subsequently received a further third on days two and three. The cows were only allowed access to one third of their total allocation at any one time and remained on each area for one day, thus taking one day to reach the desired grazing intensity (24 hour treatment).

iii. Cows received their ration as for (ii) but were only allowed access to their daily ration for 4 — 6 hours each day. After the grazing period cows were removed to a bare race for the remainder of the 24 hour period. The length of the grazing period was 6 hours under fine weather but reduced to 4 hours in adverse weather conditions (rain) (6 hour treatment).

The '6 hour' and '24 hour' treatments thus took only 24 hours to apply, but were repeated for a period of three days to average the environmental conditions facing the '72 hour' treatment.

Total areas within grazing intensities over the three day period were similar for all grazing durations consequently the daily 'breaks' of the '6 hour' and '24 hour' duration treatments were also the same size.

To reduce the numbers of animals required overall, grazing intensities were obtained by a reduction in area rather than increased stock concentration on similarly sized areas. Three cows were grazed per plot, giving 9 cows per treatment or a total of 54 cows for each experiment.

In addition to the areas occupied by the two experiments described, a similarly sized area was used for pre-treatment of the experimental animals. The cows were for the three days prior to the experiment grazed in accordance to their experimental treatment. No replication however was used in the pre-treatment, all 9 cows for each treatment being run as one mob.

2.3   Experimental Layout

Six plots, one per grazing treatment, each of sufficient size for a three day experimental period were randomized within each replicate. All '6 hour' and '24 hour' treatments were then split into three, the order in which these were grazed being decided at random. Plot dimensions (Table VIII) were such that each grazed plot was square, thus minimizing any error induced by variation in the shape of the plot. Pre-treatment plots did not have this restriction.

TABLE VIII : Experiment I and II - Plot dimensions

Grazing Intensity (cow days per acre)	Grazing Duration (hours)	Area* (acres)	Sub-plot Dimensions* (ft square)	Plot Dimensions + (ft)
120	6	0.025	33	99 x 33
	24	0.025	33	99 x 33
	72	0.075	-	57.15 ft.sq.
200	6	0.015	25.57	76.71x25.57
	24	0.015	25.57	76.71x25.57
	72	0.045	-	44.27 ft.sq.

* Areas and dimensions in these columns refer to the area
  and dimensions of the daily 'break' for the '6 hour' and
  '24 hour' treatments.

+ Refers to dimension of the total area offered over the
  three day period for all duration treatments.

The randomization for Experiment I was also used for
Experiment II. Layout of the replicates differed between the
two experiments due to the somewhat different dimensions of
the two paddocks used and the necessity of avoiding an old tree
line in Paddock 18 (Experiment I) and a small gully in Paddock
20 (Experiment II). The layout of the whole experimental area
is shown in Figure 1 and the layout of all experimental and
pre-treatment areas in Figures 2, 3, 4 and 5. Control areas
varied in size according to location and are shown for Experiment
I and Experiment II in Fig. 2 and Fig. 3 respectively.

Paddock 17

Paddock 16

Paddock 18

Roadway

Paddock 19

Race

Paddock 20

Paddock 21

Scale 1″ = 100′

Area occupied by Experiment I

Area occupied by Experiment II

Pre-treatment area, Experiment II

Pre-treatment area, Experiment I
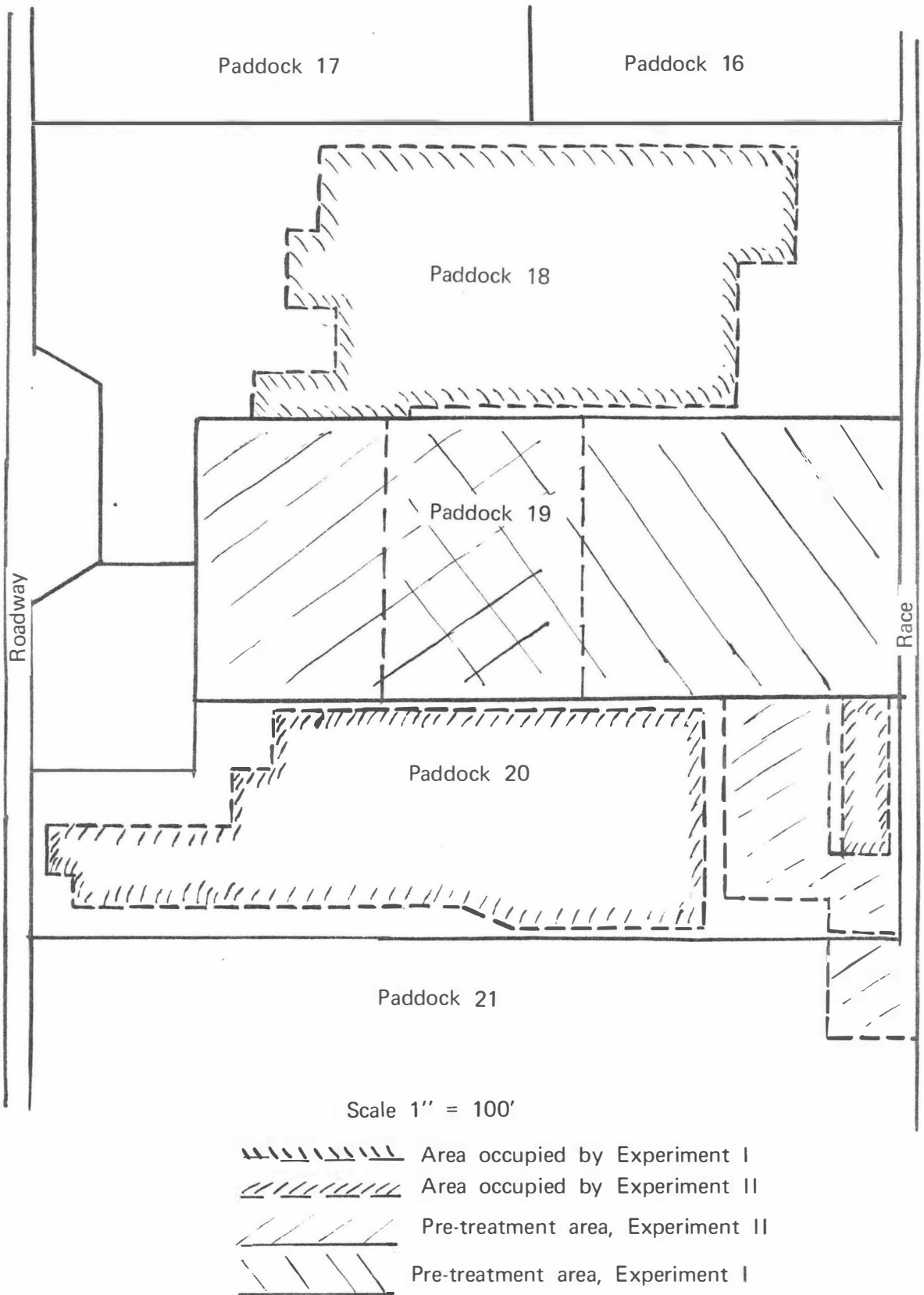
Figure 1 — General Layout of Experimental Area
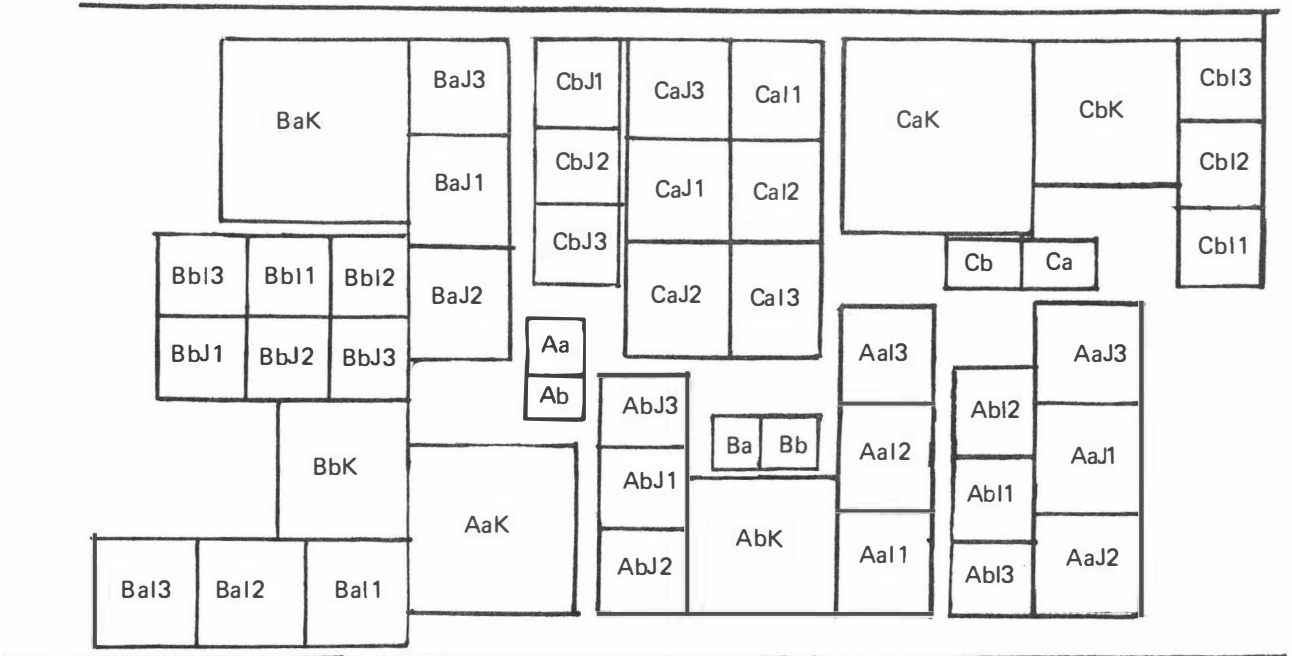
Scale 1'' = 50'

Replicate A — Replicate 1
            B — Replicate 2
            C — Replicate 3

Grazing Intensity

     a — 120 cow days per acre
     b — 200 cow days per acre

Grazing Duration I — 6 hour
                   J — 24 hour
                   K — 72 hour

Grazing Period 1 — Day 1
                 2 — Day 2
                 3 — Day 3

Figure 2 — Experiment I — Layout of plots

Paddock 18
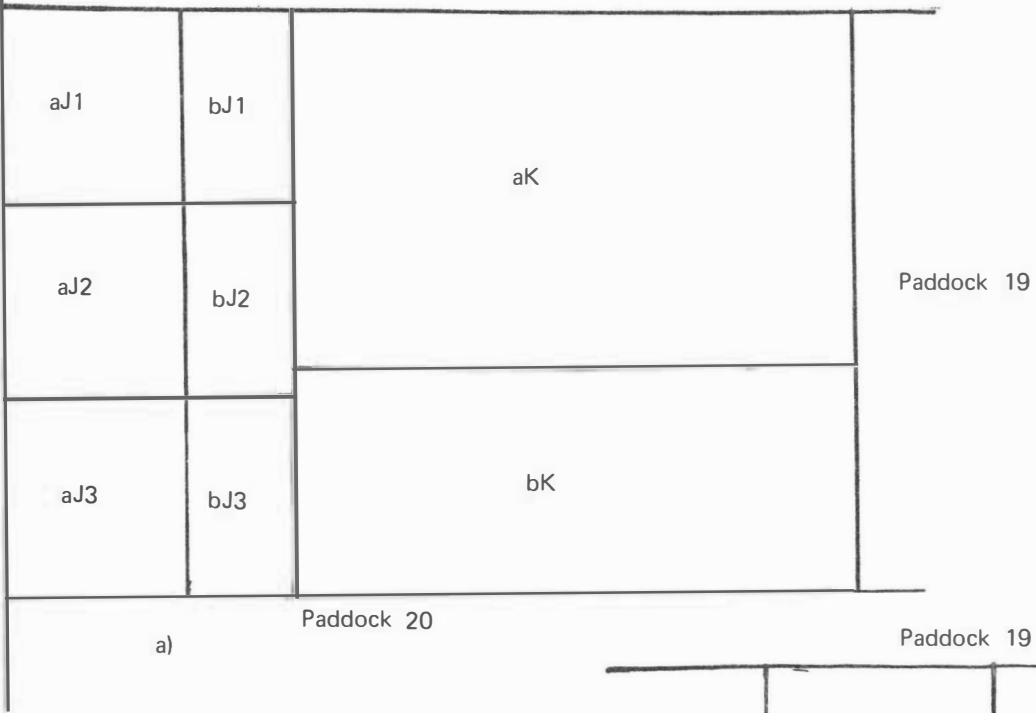
		bI3	bI2	bI1
bK		bJ3	bJ2	bJ1
aK		aI3	aI2	aI1
		aJ3	aJ2	aJ1

Race

Paddock 20

Grazing Intensity
  a — 120 cow days per acre
  b — 200 cow days per acre

Grazing Duration
  I — 6 hour
  J — 24 hour
  K — 72 hour

Grazing Period
  1 — Day 1
  2 — Day 2
  3 — Day 3

Scale 1″ = 50′

Figure 3 — Experiment I — Layout of pre-treatment plots

Paddock 19

	BaI1	BbK	BbJ1	BbI3	BaK		BaJ3	CbJ1	CaJ3		CaI1	
	BaI2		BbJ2	BbI1				CbJ2	CaJ1		CaI2	
AaI3		Aa	Ab	BbJ3	BbI2		BaJ1	CbJ3				
	BaI3							Ca	CaJ2			
AaI2		AbJ3				BaJ2	Cb			CaI3		
	AbJ1	AaK		Cbl1								
AaI1	AbK			Bb	Cbl2			CaK				
		AbJ2		Ba	Cbl3	CbK						

AaJ3 AaJ1 AaJ2

AbI2 AbI1 AbI3

70'

Replicate	Grazing Intensity	Grazing Duration	Grazing Period	
A — Replicate 1	a — 120 cow days per acre	I — 6 hour	1 — Day 1	Scale 1″ = 50′
B — Replicate 2	b — 200 cow days per acre	J — 24 hour	2 — Day 2	
C — Replicate 3		K — 72 hour	3 — Day 3	

Figure 4 — Experiment II — Layout of plots

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Paddock 18

aJ1 | bJ1 | aK

aJ2 | bJ2

aJ3 | bJ3 | bK

Paddock 19

Paddock 20

a)

Grazing Intensity
    a — 120 cow days per acre
    b — 200 cow days per acre

Grazing Duration

    I — 6 hour
    J — 24 hour
    K — 72 hour

Grazing Period

    1 — Day 1
    2 — Day 2
    3 — Day 3

Scale 1" = 50'

b)

Paddock 19

Paddock 20

aI1

aI2

aI3

bI1

Race

Paddock 21

bI2

bI3

Figure 5 — Experiment II — Layout pre-treatment plots

2.4   Experimental Methods

Prior to closing for ASP, paddocks received their annual superphosphate dressing and 5 – 6 weeks before the experimental grazing 50 lb N per acre (as urea). A schedule showing dates of closing, grazing and fertiliser application for each experiment, is given in Appendix 2.

All plots were fenced with three wire (No. 16 gauge galvanised) electric fences and where necessary, plots were separated by three foot wide races to allow stock entry to every plot. The whole of each experimental area was surrounded by at least an eight foot wide access race. Each plot had a temporary three-wire electrified gateway. Construction of fences and gateways is demonstrated in Plate I. Following grazing of Experiment I fences were dismantled and re-erected on the site of Experiment II.

Pre-treatment areas were subdivided by single-wire electric fences. As no measurements were taken on these pre-treatment plots, individual access to plots was not provided. A total of 1,375 yards of three wire and 530 yards of single wire electric fence was required for each experiment. The total 4,652 yards of wire was electrified by an 'Arko' mains electric fence unit.

Cows were allocated to treatments on a weight basis. The 54 animals were divided into nine groups of six by weight, one animal from each group was then randomly allotted to each treatment. Following pre-treatment grazing, each treatment group was subdivided into three groups by weight, one animal
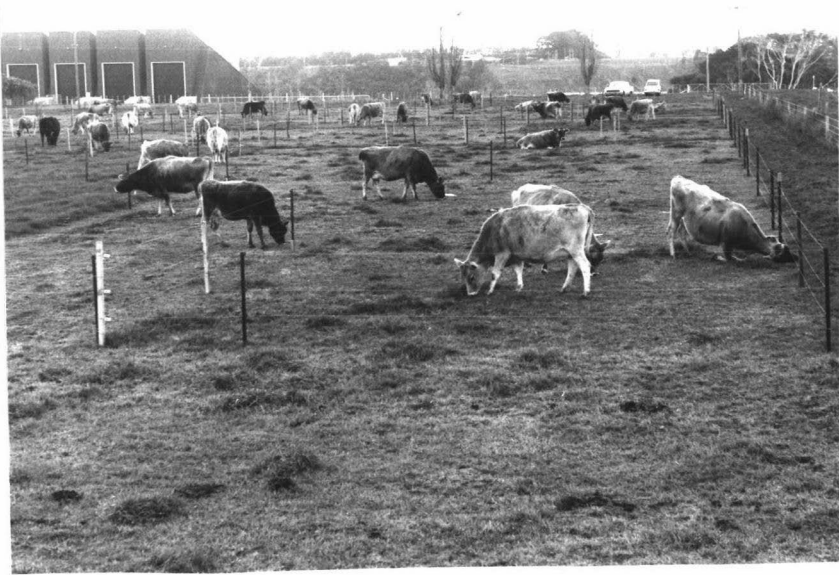
a. General View

b. General View
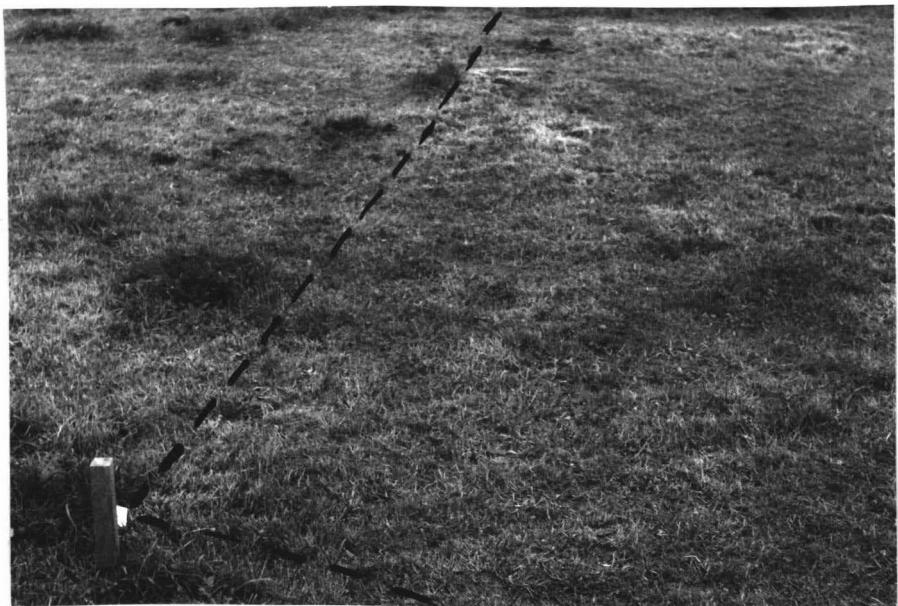
c. Herbage Rejection Sampling

Plate I -   Experiment I

from each group being randomly allotted to each replicate.
In Experiment I, one cow was replaced due to its tendency to
break through the single wire fences on the pre-treatment areas.
A large number of cows bloated on the first day of pre-treatment
in Experiment I and so, to reduce errors introduced by bloat
for the remainder of Experiment I all cows were drenched with
$\frac{3}{4}$ oz. pluronic prior to being moved to a new break (i.e. daily
for '6 hour' and '24 hour' treatments and every 3 days for the
'72 days' treatment).

2.4.1 Measurements

Pasture measurements made were of the D.M. utilization at
grazing, the D.M. regrowth following grazing and botanical
analysis and tiller counts before grazing, after grazing and
during regrowth. Regular soil moisture measurements were made
and soil bulk densities were measured at the end of each
experiment.

Environmental conditions differed between Experiments
I and II necessitating some differences in method and intensity
of measurements. Details of the methods used common to both
experiments are given in this section and those changes or
additions used for individual experiments will be given in
Section 2.4.2. A time schedule of measurements taken in
Experiment I and Experiment II are given in Appendix 2.

Dry Matter Measurements :

All pasture samples were cut with a Stewart Shearmaster electric shearing handpiece powered either by a mobile 240 volt generator or direct from 240 volt mains supply. Cutting in all cases was to ground level to ensure no grazing was taking place below the cutting height. The height of cutting, especially after grazing, meant samples taken had extensive soil contamination. All samples were washed by the method as described by Haltiner (1966) but owing to the low water pressure available the water jets were modified slightly. Samples were soaked briefly in buckets to remove the bulk of soil present before actual washing took place. The method as used appeared to give a clean sample with little or no loss due to spillage. All washed samples were allowed to drain overnight. Dry matter percentages were calculated from 200 gm sub-samples oven dried at 80°C for 24 hours. Samples were weighed to 0.1 g.m.

(i) Dry matter utilization

Pasture dry matter was measured both pre and post-grazing, the difference between these two measurements was taken as the dry matter utilization by the grazing animal. Three 1 ft x 3 ft quadrats were cut from each plot on the day prior to and the day following grazing. Harvest was thus spread over a three day period. The three samples per plot were bulked, then washed and subsampled as one composite sample. In the control plots two 1 ft x 3 ft quadrats were cut per plot.

(ii) Dry Matter production

Regrowth on defoliated areas was measured by taking
samples as described for the pre and post-grazing estimates.
Three 1 ft x 3 ft quadrats were cut from grazed plots and two
from control plots. Plots were sampled at ten day intervals.
Regrowth at Day 0 was estimated from the post-grazing figures,
with six further ten day cuts in Experiment I and five in
Experiment II.

Botanical Analysis :

. Following draining, washed samples were subsampled for
botanical determination. The size of sub-sample varied from
25 gm in very short post-grazing material to 75 gm in longer
pre-grazing and final regrowth material. Where necessary
samples were stored under refrigeration. Botanical analysis
samples were hand separated into ryegrass, timothy, cocksfoot,
Poa species, other grasses, weeds and clovers. Each fraction
was oven dried at 80°C for 24 hours and then weighed (to 0.01
gm) and from this percentage occurrence and dry matter production
for each sub-group was determined.

Tiller Counts :

Tiller counts were taken by the method of Mitchell and
Glenday (1958) prior to grazing and three times following
grazing. Twenty, 2" diameter plugs were taken per grazed
plot and ten per control plot sampled. Plugs were dissected
and all tillers and rooted clover nodes counted. A rooted
clover node was counted only if some leaf was also present at
that node.

The timing of post-grazing samples was such that it was endeavoured to measure tillers that recovered from grazing. Sampling was delayed 7 - 10 days following grazing for this purpose. The third and fourth measurements were than taken at four weekly intervals in Experiment I and three weekly intervals in Experiment II.

Ground Cover :

The percentage ground cover was determined by point analysis, one hundred points being taken per grazed plot and fifty per control plot. Each point was recorded as either a hit on vegetation or bare ground.

Soil Moisture :

Soil moistures were determined from six, 1" diameter core samples, taken to a depth of 4" from each plot. The top $\frac{1}{2}$" of each core was discarded to eliminate basal plant material. Cores were bulked for each plot and oven dried at $80^{\circ}C$ for 24 hours. Moisture percentages were calculated on an oven-dry basis. Measurements were made at fortnightly intervals on all plots.

Bulk Density :

Toward the end of each experiment soil bulk density estimations were made on all plots by the method used by Edmond (1964). A core sampler (surface area 2.46 cm^2) was used and measurements made for the 0 - 3 cm, 3 - 6 cm, 6 - 9 cm and overall 0 - 9 cm depths. Five cores were taken per plot, bulked and oven dried at $100^{\circ}C$ for 24 hours. Any cores showing worm holes were discarded and new cores taken.

2.4.2

(i) <u>Experiment I</u>

<u>Dry matter utilization</u> :

Grazing in Experiment I, especially at the lighter
stocking rate resulted in some noticeable pasture rejection
surrounding dung pats. An estimation of the size of this
effect was gained by cutting at least 170 ft^2 with a rotary
mower set at the general grazing height of those areas on the
plot where no rejection took place. In all '72 hour' treatments
a representative quarter of each plot was harvested, while for
the '6 hour' and '24 hour' treatments within each replicate a
representative plot was chosen from the three available, and
half the area of these plots was harvested. The pasture harvested
was washed and the whole sample oven-dried. Areas defoliated by
rotary mower were avoided for the remainder of the experiment
whenever measurements were taken.

<u>Botanical Analysis</u> :

Full analysis was carried out on all samples from pre-grazing
post-grazing and regrowth cuts 1, 3, 5 and 6.

<u>Tiller Counts</u> :

Due to the continued fine weather at the time of grazing
it was thought adequate to sample one plot per treatment per
replicate (i.e. samples for '6 hour' and '24 hour' treatments
were only taken from one day of three). The plot sampled was
decided at random before grazing and all subsequent measurements
were made on these plots.

Ground Cover :

An estimate of the percentage of bare ground in each plot was made two weeks after grazing.

(ii) Experiment II

Dry matter utilization :

The objective in post-grazing harvests was to recover all pasture not utilized, which meant, that under the wet conditions experienced in Experiment II pasture that was buried and/or submerged, required sampling. Frames were placed, all loose lumps of mud and soil were collected, and then the site was defoliated to ground level. Buried pasture was then raked upright with a 10" garden rake and the sample site once more cut to ground level. Recovery of green material appeared satisfactory but appreciable root contamination was present, mainly from debris washed from the lumps of mud and soil collected prior to cutting. Following washing, sub-samples (approximately 25 gm) were taken and the root fraction separated by hand. All attached roots were dissected at the root-stem junction. Post-grazing D.M. yields were subsequently corrected for root contamination.

Botanical Analysis :

Full analysis was carried out on all samples from pre-grazing and regrowth cuts 1, 3 and 5. Dissection in the post-grazing samples was for root contamination only.

Tiller counts :

All plots were sampled at all sample dates.
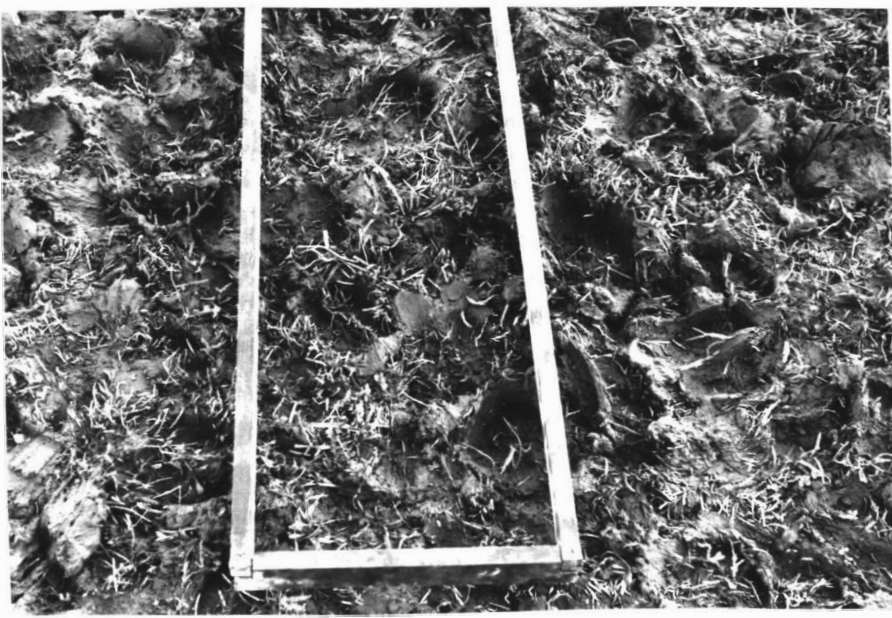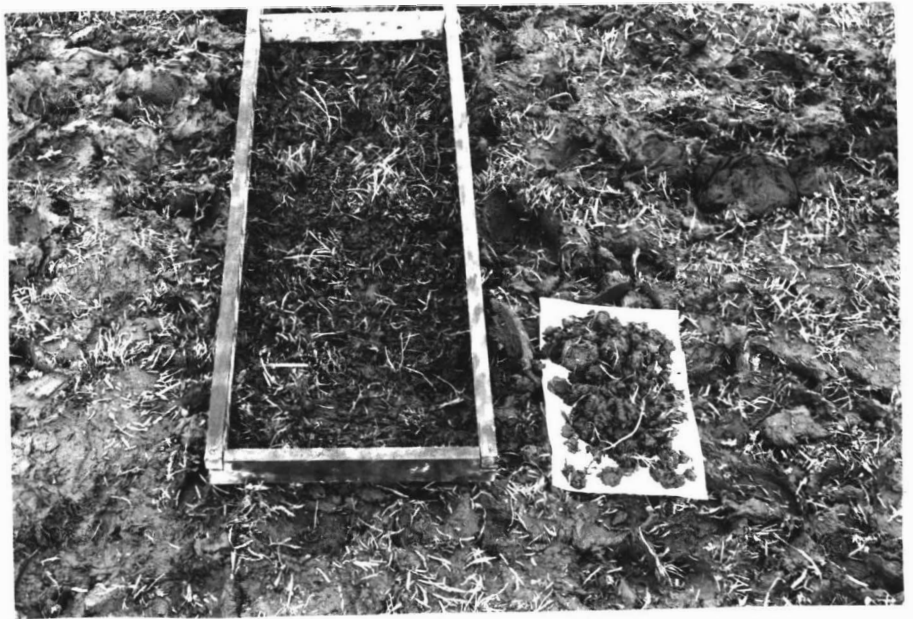
Plate II - Sampling on Pugged Pastures(see page 75)

Ground cover :

No estimate was made two weeks after grazing, as in
Experiment I, due to lack of time.

2.4.3 Statistical Methods

2.4.3.1 Identical statistical proceedures were carried out for
both experiments. The main statistical method used was that of
analysis of variance and in general three comparisons were made
on each set of data.

(i) Three way analysis of variance comparing, replicates

x grazing intensity x grazing duration of the general
model (adapted from Sokal and Rohlf, 1969).

$$Y_{ijkl} = m + R_i + S_j + T_k + (S\ T)_{jk} + e_{ijkl}$$

where R stands for replicates, S for grazing intensity and
T for grazing duration. m represents the population mean
and e_{ijkl} an independent, normally distributed variable with
mean $\bar{e}_{ijkl} = 0$ and variance $0^2_e = 0^2$. The value of subscripts
are : –

$$i = 1, .., 3$$
$$j = 1, .., 2$$
$$k = 1, .., 3$$
$$l = 1, .., n$$

In most cases only one measurement is available per plot
making n = 1 and therefore eliminating the term l from the
above equation. The model is mixed, in that replicate effects

are assumed to be random and grazing intensity and grazing duration effects fixed. In the analysis of variance all Rep x Treatment interactions are incorporated in the error term giving the analysis layout as shown in Appendix 3.

The grazing duration values tested in this analysis are the '72 hour' treatment compared with the mean value for the three estimates for each of the '6 hour' and '24 hour' treatments per replicate. This mean value being the average reaction of these two grazing duration treatments to the environmental conditions experienced during the course of the '72 hour' treatment.

(ii) Four-way analysis of variance comparing, replicates x grazing intensity x grazing duration x days of the general model (adapted from Snedecor and Cochran, 1967).

$$Y_{ijks} = m + R_i + S_j + T_k + (S\ T)_{jk} + e_{ijk} + D_s + (DS)_{js}$$
$$+ (DT)_{ks} + (DST)_{jks} + e_{ijks}$$

where R stands for replicates, S for grazing intensity, T for grazing duration, and D for days. This is a split-plot design with R, S and T being the main effects and D the sub-plot effect. m represents the population mean and e_{ijk} and e_{ijks} the error components for main plots and sub-plots respectively. The values of the subscripts are : —

$$i = 1, \ldots, 3$$
$$j = 1, \ldots, 2$$
$$k = 1, \ldots, 2$$
$$s = 1, \ldots, 3$$

The model is mixed, in that replicate effects are assumed random and all other treatment effects fixed. The composition of the respective error terms in the analysis of variance are shown in Appendix 3.

This analysis is used for testing the '6 hour' and '24 hour' grazing duration treatments only. It is used predominantly as a measure to look at effects between the three days over which these treatments were repeated within each experiment. Results from the main effects are disregarded as these have been previously analysed in the three-way analysis (Section (i) above).

(iii) Three-way analysis of variance comparing replicates x grazing intensity x defoliation method (i.e. whether plots have been cut or grazed). The general model is similar to that of Section (i) above where T would now represent defoliation treatment and subscript k would only represent two values.

The control (cut) plots are compared with the mean values of all the grazed plots within the two grazing intensities studied.

Analysis of variance was carried out using a generalised multi-factorial analysis of variance programme on the IBM 1620 model 2 computer at Massey University. The print-out was as a Model I analysis and this was then amended using a desk calculator to incorporate the mixed model design.

2.4.3.2   Where necessary the least significant difference
(LSD) between means was calculated according to the equation : -

$$\text{LSD}_{(0.1)} = t_{(0.1)} \times \left(\frac{2 \times \text{EMS}}{n}\right)^{\frac{1}{2}}$$

$$(0.05) \qquad (0.05)$$

$$(0.01) \qquad (0.01)$$

$$(0.001) \qquad (0.001)$$

where t is the appropriate t value for the df in the error
mean square (EMS) at the 10% (0.1), 5% (0.05), 1% (0.01) or
0.1% (0.001) level of probability. The EMS used in each case
was the EMS from the appropriate analysis of variance calculation.
n is the number of observations per mean.

In all analysis of variance and t-test results presented,
the conventional notation for levels of significance will be
used; that is $p < 0.1$ is denoted by [+] , $p < 0.05$ by *,
$p < 0.01$ by **, and $p < 0.001$ by ***.

2.4.3.3 Analysis of covariance was performed when significant
differences appeared in the analysis of variance of the pre-
grazing D.M. sample. Post grazing and regrowth D.M. means
were adjusted for differences existing prior to grazing.
Covariance gave only slight alteration to the means and had
little effect on significant differences shown by the analysis
of variance, so as a consequence is not presented.

2.4.3.4 Relative growth rates

It was thought desirable to fit some standard model to each set of D.M. regrowth data. Orthoganal polynomials (Snedecor and Cochran 1967) were used but in Experiment I no justification was obtained for departure from a straight line. Consequently this method was abandoned.

Logistic curves such as those fitted by Brougham (1959) and Hunt (1968) probably have greater biological significance than the fitting of a general polynomial. Such curves are derived from the assumption that the rate of D.M. growth is proportional to the weight at any instant and to the maximum weight than can be obtained. Logistic curves could not be attempted as maximum yields had not been obtained in D.M. regrowth in either Experiment I or II when they were discontinued. It was attempted therefore to fit log curves, based on the assumption that growth at any stage is proportional to the amount present at any instant.

Log curves are based on the relationship (Snedecor and Cochran 1967)

$$\frac{dW}{dt} \; = \; bW \quad \text{———————} \quad (1)$$

where W is D.M. yield in lbs/acre, T is time in days and b is the constant relative rate of increase. This leads to the relationship :

$$\log_e W^* \; = \; \log_e A + bT \quad \text{—————} \quad (2)$$

where A is a constant and W, b and T are as previously defined.

* Unless otherwise stated all log data appearing in this text is based on $\log_e$ and not $\log_{10}$.

The regression (2) was fitted to all D.M. regrowth data. Regressions were fitted to individual plots and then averaged over treatment means. Curves were only fitted to regrowth data from day 10 onwards. Due to the different sampling method used in the post-grazing harvest (Section 2.4.2) it was thought desirable to omit this data. In Experiment I in the early stages of regrowth the log curve did not fit the production data as well as a straight line regression. It was thought more desirable however, to use a standard method (log regression) rather than use normal straight line regressions in Experimental I and log regressions in Experiment II.

C H A P T E R   III

RESULTS — EXPERIMENT I

3.1   Grazing intensity v's grazing durations.

3.1.1   Cow weights

The weights of cows used for Experiment I ranged from
500 lb to 1012 lb liveweight with a mean value of 722 lb.   Table
IX gives the mean weight of the nine cows allocated to each
treatment.   It appears that the weight of those animals on the
higher grazing intensity were on the average 35 lb lighter than
those on the lower intensity.   Analysis of variance (Appendix
4) showed this difference to be non-significant.

TABLE   IX   :   Experiment I – Cow weights (lbs liveweight)

		Grazing intensity	(Cow days/acre)
		120	200
Grazing	6	752.2	697.1
duration	24	735.1	697.1
(hours)	72	730.3	718.4
S.E. Mean ±		26.02	

3.1.2   D.M. Utilization and 'Intake'

D.M. consumption over the grazing period is presented
in two forms, the intake* in lbs per cow per day and the
utilization per acre in lbs D.M. consumed for each 100 lbs D.M.

* The term 'intake' refers to the difference between pre and
post-grazing estimates which is attributed to animal intake.

presented at grazing (expressed as a percentage).

The average intake per cow per day was 10.84 $\pm$ 0.44 lb D.M. Table X gives the mean intake per animal and percentage utilization for each grazing intensity and duration. Analysis of variance (Appendix 5) indicated no significant differences in intake due to duration but showed the 4 lb D.M. difference in daily intake per cow between the two grazing intensities to be highly significant ($p < 0.01$).

TABLE X : <u>Experiment I - Daily D.M. intake and percentage utilization</u>

		Intake (lbs DM/cow/day)	Percent Utilization
Grazing intensity	120	12.84	69.5
(cow days/acre)	200	8.84	81.8
SE Mean $\pm$		0.623	1.34
Difference		4.00 **	12.3 ***
Grazing duration	6	10.10	72.5
(hours)	24	10.53	79.3
	72	11.89	75.2
SE Mean $\pm$		0.763	1.65
LSD (0.05)		2.40	5.19

The extra 12.26 lb DM consumed per 100 lb DM offered with the increase in grazing intensity from 120 to 200 cow days per acre was highly significant ($p < 0.001$). There was also a significant difference ($p < 0.05$) between durations in the

percentage utilization of DM. A t-test (Appendix 5) showed
the percentage utilization with '24 hour' grazing to be
significantly higher $(p < 0.05)$ than for '6 hour' grazing but
not significantly greater than the '72 hour' treatment.

3.1.3   D.M. Production

Results are presented in Figure 6 showing the D.M.
production over the experimental period for each grazing
duration at the two grazing intensities studied. Mean values
for grazing intensity and grazing duration effects are presented
in Table XI while data, analysis of variance and t-test results
appear in Appendix 6-1, 6-2 and 6-3 respectively.

For D.M. production the analysis of variance of comparisons
over the three durations and two grazing intensities were
analysed in a joint analysis with the grazing techniques v's
grazing intensity analysis at variance. Only those results
relevant to grazing intensity v's grazing duration will be
presented in this section.

Table XII summarizes the results of analysis of variance
carried out on DM data at each harvest date.

The significant grazing duration effect $(p < 0.05)$ in
the pre-grazing harvest is shown by t-test to be the result of
the '72 hour' treatment having significantly more D.M. at this
stage than both the '6 hour' $(p < 0.1)$ and '24 hour' $(p < 0.05)$
treatments. In terms of D.M. this increase was 266 and 407 lb
D.M. per acre for the '72 hour' treatment over the '6 hour' and

TABLE XI : Experiment I - D.M. Production (lbs DM/acre)

| | | Pre- | Post- | Harvest (days from grazing) | | | | | |
				10	20	30	40	50	60
Grazing intensity	120	2176	670.9	760.6	890.0	983.7	1302	1568	1918
(cow days/acre)	200	2139	394.6	516.8	599.4	717.1	951.8	1199	1529
Diff. 120 - 200		37	276.3	243.8	290.6	266.6	349.9	368.6	389.4
LSD (0.001)		493.0	120.0	165.0	109.6	130.7	194.0	161.5	404.5
SE Mean ±		84.20	21.70	28.19	18.56	21.88	33.12	27.57	69.46
Grazing duration	6	2145	588.5	692.7	823.2	919.2	1190	1396	1630
(hours)	24	2004	419.2	528.0	623.8	781.7	1063	1300	1557
	72	2411	590.5	695.3	787.2	850.3	1128	1454	1835
LSD (0.05)		312.8	80.6	104.7	68.9	81.2	123.1	102.5	258.0
SE Mean ±		103.09	26.57	34.51	22.72	26.80	40.55	33.76	85.05

TABLE XII : <u>Experiment I - D.M. production, significant results</u>

| | Pre- | Post- | Harvest (days from grazing) | | | | | |
			10	20	30	40	50	60
Grazing intensity	n.s.	***	***	***	***	***	***	**
Grazing duration	*	***	**	***	*	n.s.	*	+
Interaction	n.s.	n.s.	n.s.	+	n.s.	n.s.	+	n.s.
Replicate	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
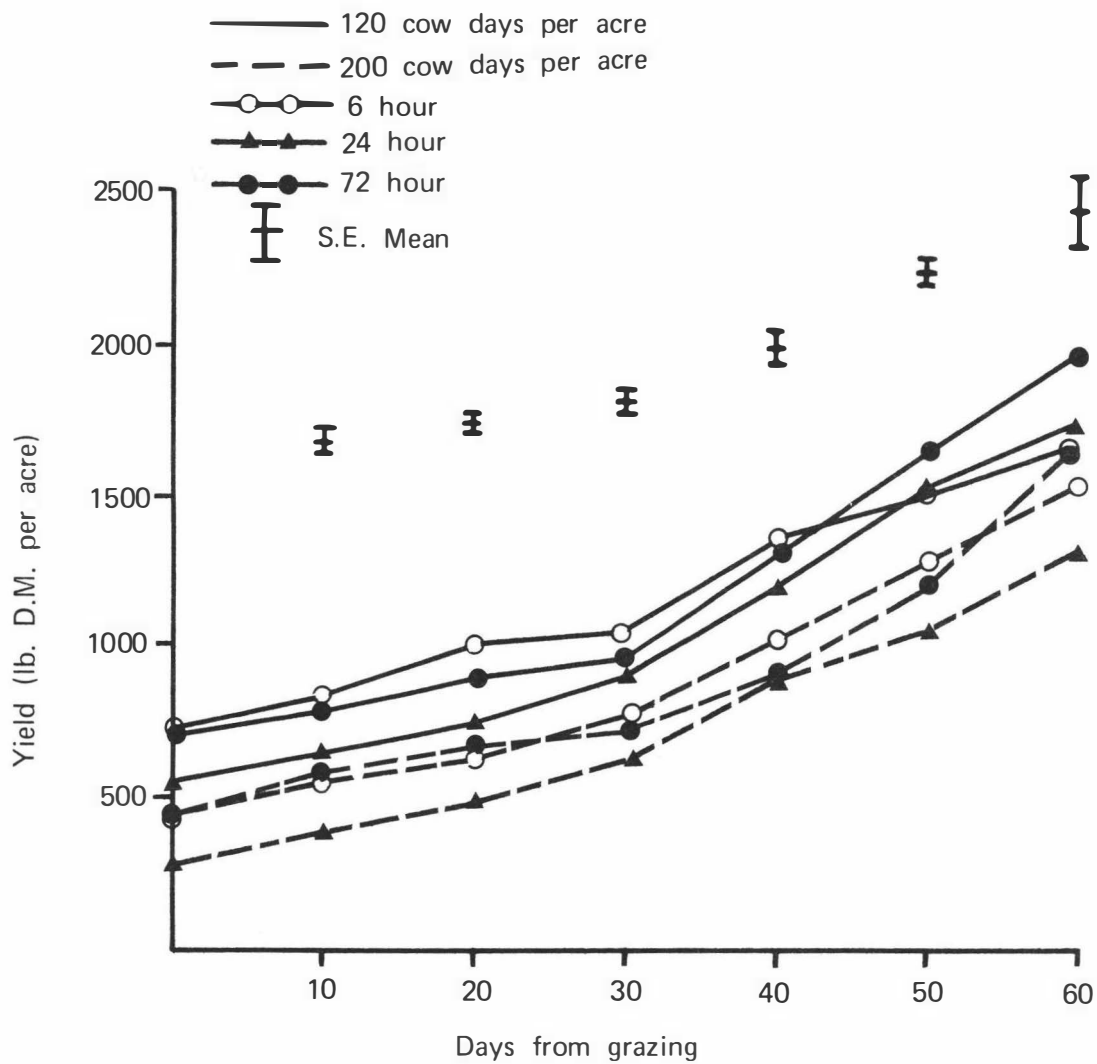
Figure 6 — Experiment I — The effect of grazing intensity and grazing duration on D.M. production.

'24 hour' treatments respectively. As mentioned in Section
2.4.3.3 correction of regrowth figures for this difference by
covariance analysis had little effect on means or analysis of
variance results.

Grazing intensity :

Table XII shows a highly significant $(p < 0.001)$ grazing
intensity effect throughout the regrowth period except for a
slightly less significant $(p < 0.01)$ result at the last sample
date.

The differences between grazing intensity means and the
LSD values for $p < 0.001$ are given in Table XI. Reducing the
grazing intensity from 200 cow days per acre to 120 cow days
per acre increased post-grazing D.M. yields by 276 lb D.M. per
acre. Over the regrowth period this trend increased in absolute
terms till 60 days later the difference was 389 lb D.M. per
acre. In relative terms however the 70% increase in D.M. at
the low grazing intensity at the post-grazing harvest is reduced
by day 60 to an increase of only 25%.

Grazing duration :

The significant results shown in Table XII for post-grazing
and regrowth harvests at days 10 and 20 is due to the '24 hour'
duration treatments having significantly less DM than both the
6 and 72 hour treatments (Table XI). t-tests carried out within
intensity x duration means show the interaction $(p < 0.1)$ at

day 20 due to the '6 hour' treatment having significantly more
DM than the '72 hour' treatment $(p < 0.01)$ in the 120 cow days
per acre plots but having less (though not significantly less)
in the 200 cow days per acre plots. This effect can be observed
graphically in Figure 6. At the 4th regrowth harvest (Day 30)
the '24 hour' treatment still has less DM than both the '72 hour'
$(p < 0.1)$ and '6 hour' $(p < 0.01)$ treatments. The '6 hour'
duration has now significantly more DM than the '72 hour' treatment
$(p < 0.1)$ but unlike the previous harvest the effect here is
similar at both grazing intensities. Differences at the 5th
harvest were almost identical to the previous harvest, but
owing to the increased variability at this harvest the differences
were no longer significant.

The final two harvests (days 50 and 60) show the '6 hour'
treatment to be loosing its supremacy and the interaction at
day 50 is caused by this falling off being more marked and
occurring at an earlier stage in regrowth in the lower of the
two grazing intensity treatments. At day 50 the '24 hour'
treatment still has significantly less DM than both the '6 hour'
and '72 hour' treatments $(p < 0.01)$ while at day 60 it is only
significantly lower than the '72 hour' treatment $(p < 0.05)$.
In these two final harvests the '72 hour' treatment produced
more DM than the '6 hour' treatment, but the difference failed
to reach significance.

3.1.4   Relative Growth Rates

Table XIII gives the coefficients and constants for
grazing intensity x grazing duration treatments of the regression
of log DM with time. Regressions were fitted on regrowth data
from day 10 to day 60.

TABLE XIII : Experiment I – Regression log DM on time for grazing intensity and grazing duration.

		120 cow days per acre			200 cow days per acre		
		Coeff.	S.E.*	Constant	Coeff.	S.E.*	Constant
Duration	6	0.014	0.001	6.58	0.022	0.001	6.04
(hours)	24	0.021	0.001	6.22	0.025	0.001	5.73
	72	0.019	0.002	6.42	0.021	0.002	6.07
LSD (0.001) (0.05)		0.007	(0.004)				

* S.E. are based on the deviations of mean values about fitted regressions.

Analysis of variance of the regression coefficients (b values) is given in Appendix 6-4. This analysis showed highly significant $(p < 0.001)$ differences due to grazing intensity and grazing duration and also a significant $(p < 0.1)$ interaction. The difference in mean duration b values, over the two grazing intensities, is shown by t-test to be due to the '24 hour' treatment having a significantly higher b value than both the '6 hour' $(p < 0.001)$ and '72 hour' $(p < 0.05)$ treatments.

The interaction between intensity and duration reflected the low coefficient for the '6 hour' treatment at the 120 cow days per acre grazing intensity (Table XIII).

3.1.5 Botanical Composition

3.1.5.1 In all sections in Chapters III and IV dealing with botanical composition of DM regrowth, analysis of variance was performed on the production of each individual component at each harvest on which botanical separation had been made. Results from statistical analysis were variable and many significant differences displayed between treatments by analysis of variance, were in agronomic terms meaningless, as the differences involved were so small. Analysis as such will not be given, but in each section botanical composition will be discussed with the intention of looking for major trends between treatments in botanical composition and DM production of individual species.

3.1.5.2   At the final harvest (day 60) the ryegrass component of the sward contributed 10 percentage units more to DM production than had been the case in the pre-grazing harvest (50% compared to 40%). Ryegrass increased mainly at the expense of timothy and unsown grasses. Individual treatments had very little effect on the botanical composition of regrowth and therefore only the botanical composision of the mean DM production for all treatments is presented in Figure 7.

Over the experimental period species composition, expressed as a percentage, of the mean grazing intensity and grazing duration treatment effects (Appendix 7) showed little variation due to treatment except for dead matter immediately following grazing. After grazing dead material formed a major component of DM production measurements but fell to pre-grazing levels 30 days later (Figure 8). Dead matter component was enhanced by the highest grazing intensity (Figure 8a) and the '72 hour' grazing duration (Figure 8b).

3.1.6   Tiller Density

Tiller counts were made on ryegrass, timothy, cocksfoot, Poa species, other grass species and rooted clover nodes. At each sample date analysis of variance (Appendix 8) was carried out for each species along with an analysis of total sown grass (ryegrass + timothy + cocksfoot), total unsown grass (Poa species and other grasses) and total grass (total sown grass + total unsown grass) components.
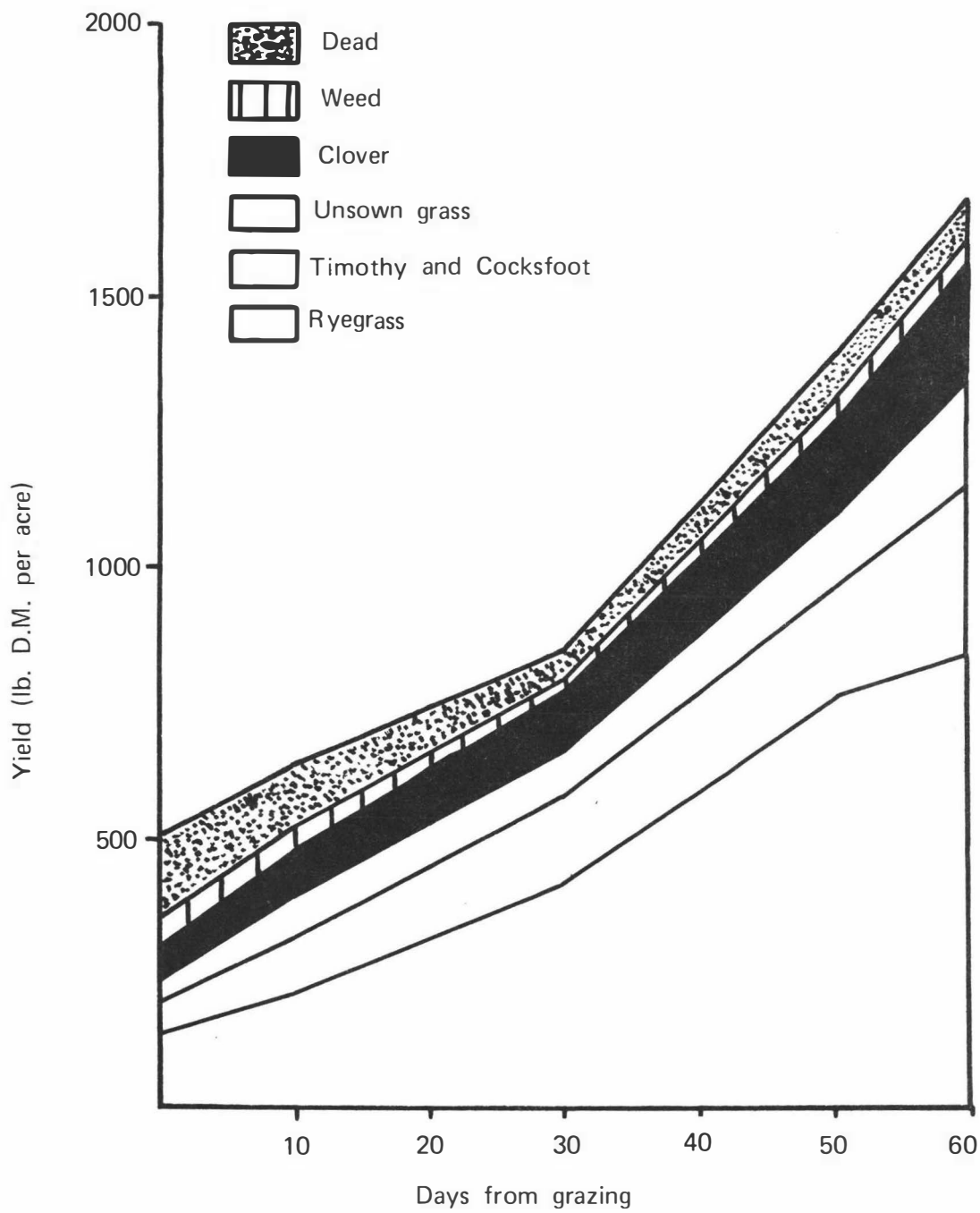
Figure 7 — Experiment I — Botanical composition of regrowth
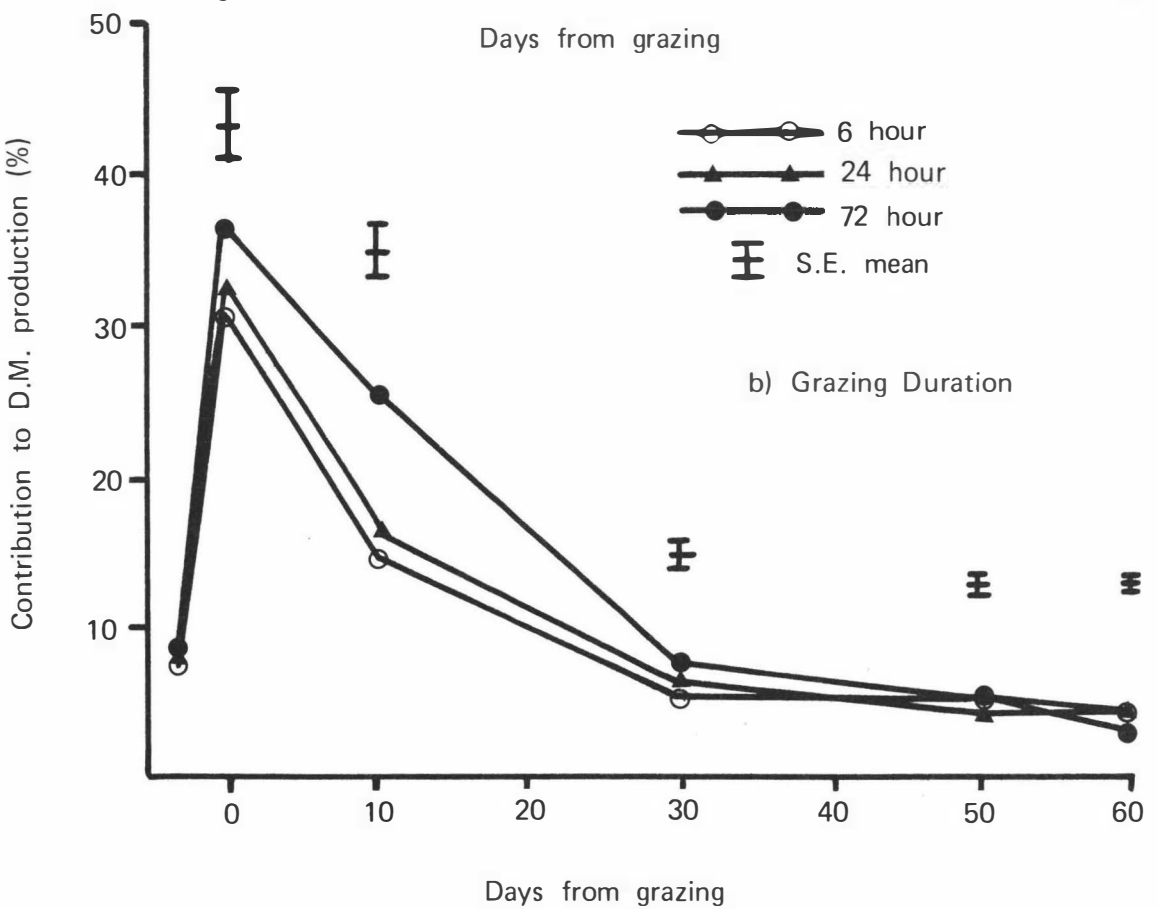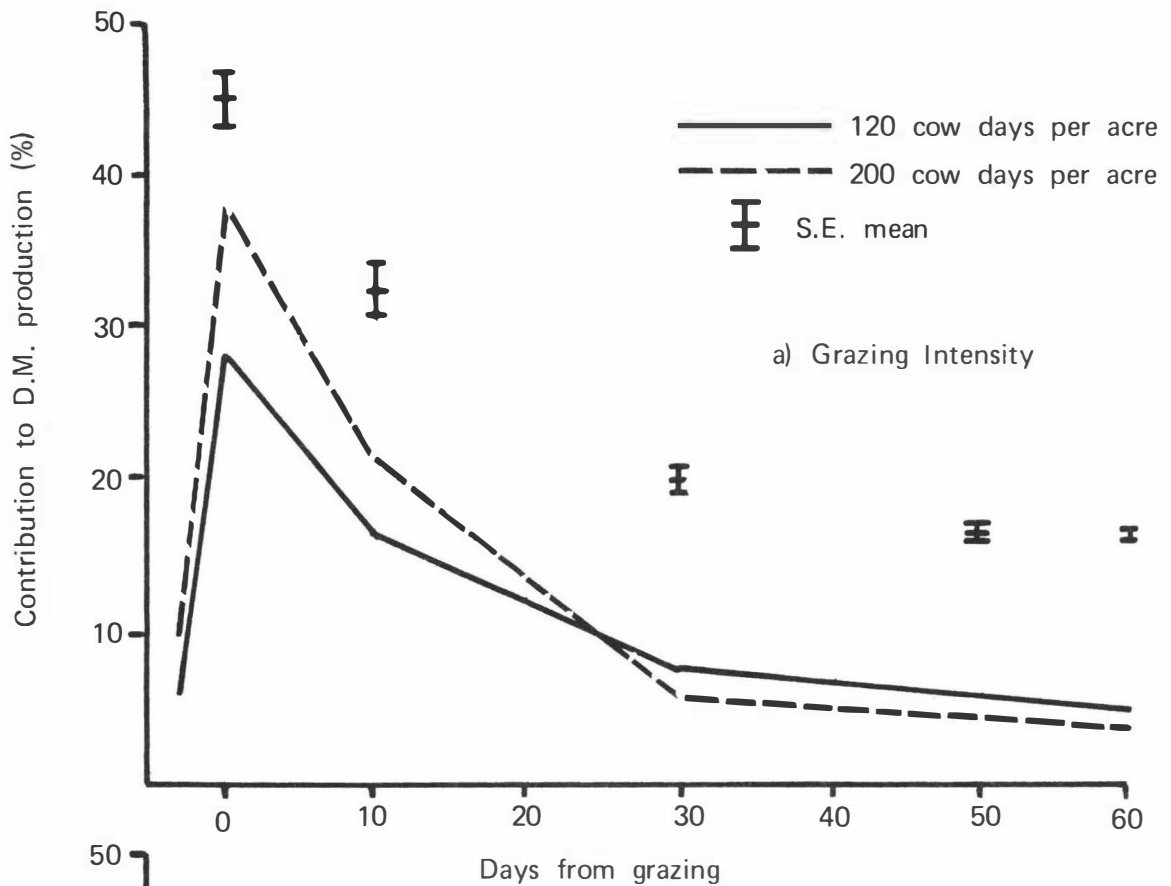
Figure 8 — Experiment I — Grazing duration and intensity effect on dead matter contribution to D.M. production.
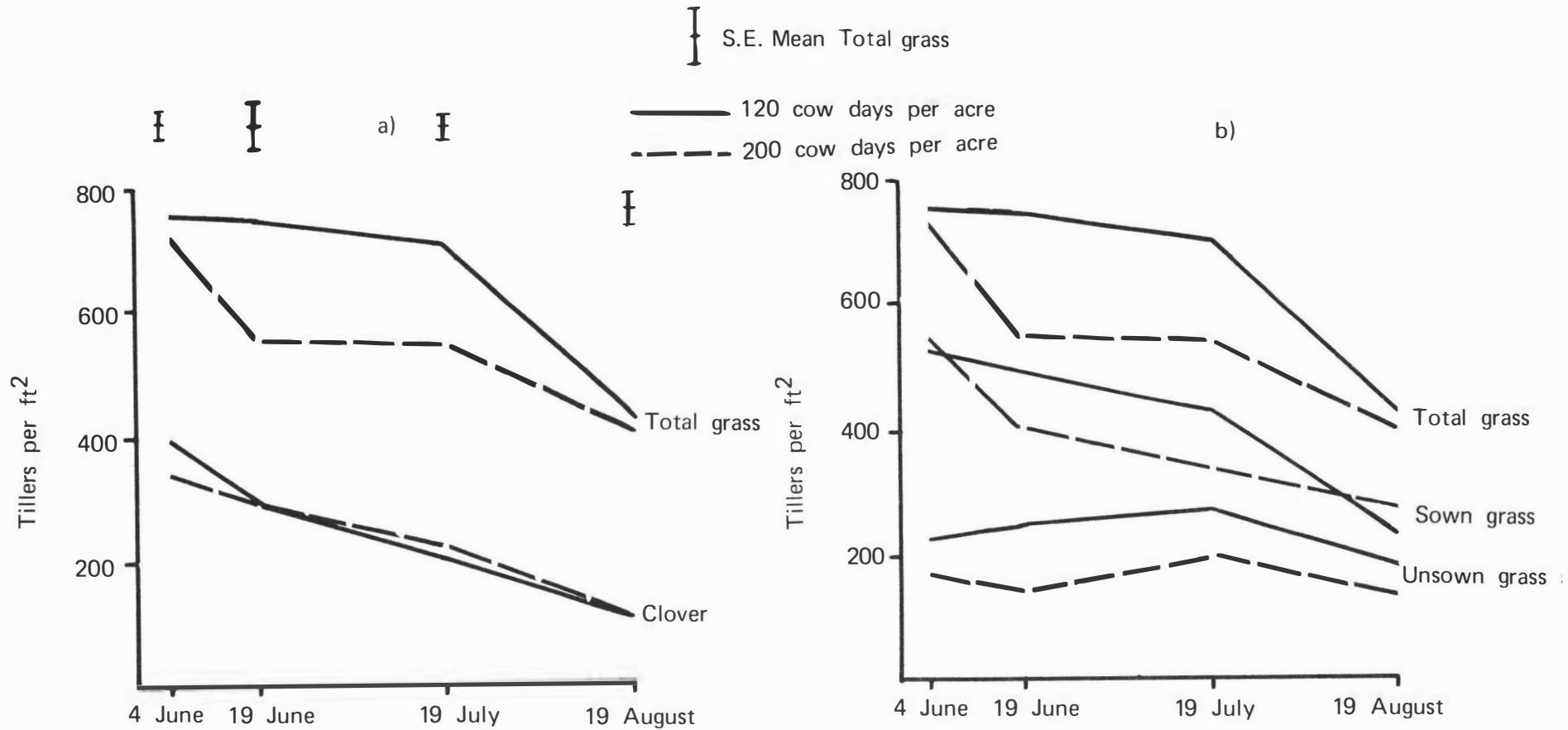
Figure 9 — Experiment I — The effect of grazing intensity on tiller populations
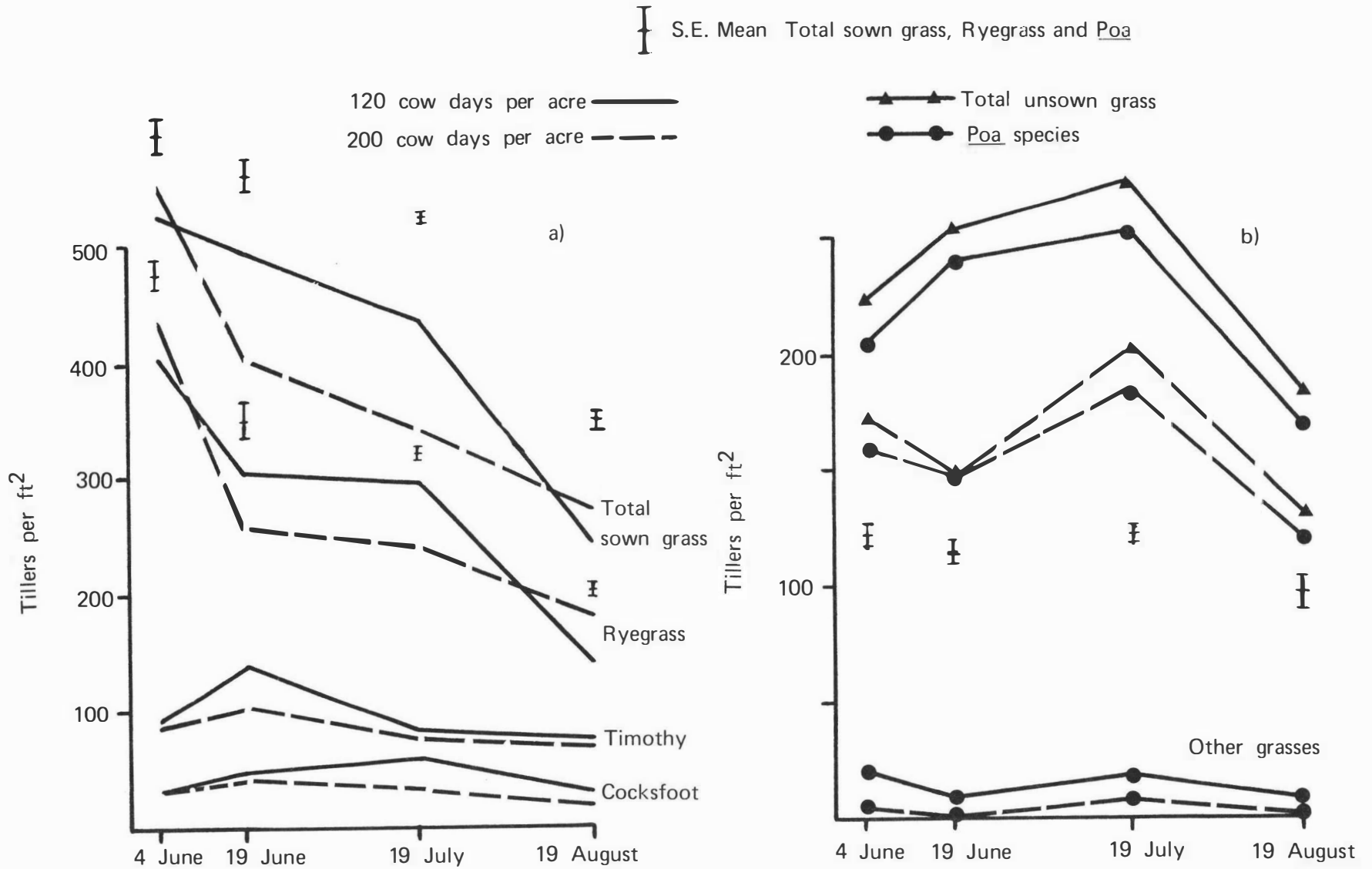
Figure 10 — Experiment I — The effect of grazing intensities on tiller populations

Clover nodes

The treatments imposed appeared to have little effect
upon clover nodes. Numbers decreased linearly (Figure 9a)
regardless of treatment from a mean density of 368.7 ± 27.6
to 104.0 ± 3.5 per square foot.

Total Grass tillers

From a mean density of 736 ± 19.9 tillers per square
foot prior to grazing, total grass tillers declined to a density
of 415 ± 20.9 tillers per square foot at the final sample date.
At both these times there was no significant difference between
grazing intensity treatments. The character of this decrease
was however different between the two grazing intensities
(Figure 9a). Grazing produced an immediate and marked reduction
in tiller numbers at the high grazing intensity but not the low
intensity, resulting in significantly fewer total grass tillers
at the 200 cow days per acre treatment at both the second
($p < 0.01$) and third ($p < 0.001$) harvests.

Total Sown Grass Species

Unlike total grass tillers, those of the sown species
show a continual decrease over the experimental period (Figure
9b). As with the total grass tillers the higher grazing intensity
significantly reduced the tiller numbers, compared with the low
intensity, at both the second ($p < 0.05$) and third ($p < 0.01$)
samples.

The total sown grass tiller numbers are largely a reflection of the ryegrass component (Figure 10a). Grazing appeared to reduce ryegrass tillers at both grazing intensities, the reduction being the greatest at the highest intensity. The difference between intensities reached significance ($p < 0.05$) at the third sample. The reduction in tiller numbers between 19 July and 19 August was greater at the lower grazing intensity to the extent that by 19 August there were fewer ryegrass tillers per square foot at the lower grazing intensity ($p < 0.1$).

Timothy and cocksfoot tillers formed a smaller component of the sown grass total, but both species appeared less influenced by grazing or grazing intensity than was the case with ryegrass tillers. At 19 June and 19 July, 200 cow days per acre gave a significant reduction in cocksfoot tiller density over the 120 cow days per acre ($p < 0.1$).

Total Unsown Grass Species

The stability of total tiller population between 19 June and 19 July, despite reduction in the sown species was caused by an increase in unsown species over this period. For the first six weeks unsown grass tiller populations increased under both grazing intensities. A small non-significant difference between grazing intensities at the pre-grazing period became more marked (Figure 10b) and significant on 19 June and 19 July ($p < 0.05$). Analysis of variance (Appendix 8) showed a significant grazing intensity x duration interaction ($p < 0.1$) in sample 2, it was shown by t-test (Appendix 8) that the

increase in tiller numbers at the lower grazing intensity was due to the '6 hour' and '72 hour' duration treatments only.

Due to the small numbers of other grass species in Experiment I all changes in unsown species are due to changes in Poa species.

Grazing Duration

Grazing durations appeared to have a variable and inconsistent effect upon tiller populations. Analysis of variance (Appendix 8) shows a significant grazing duration effect in both total grass ($p < 0.05$) and sown grass species ($p < 0.1$) on 19 July. The grazing duration treatment means for total grass species are presented in Table XIV. A t-test shows the '24 hour' treatment to have significantly fewer total grass tillers than the '6 hour' ($p < 0.1$) and '72 hour' ($p < 0.05$) treatments. This reflects the position in the sown species where the '24 hour' treatment has fewer tillers than both the other two treatments, but significance is only reached between the 24 hour and 72 hour treatments ($p < 0.05$). The main component of the difference appears to be ryegrass, though differences were not significant in the individual species.

TABLE XIV : Experiment I — the effect of grazing durations on total grass tiller populations (tillers/ft^2)

		4 June	19 June	19 July	19 August
Grazing duration	6	730	716	640	439
(hours)	24	754	609	564	410
	72	726	627	688	396
S.E. Mean ±		34.4	51.4	27.9	36.2
LSD (0.05)		108.5	162.0	87.9	114.1

3.1.7 Ground Cover

Table XV gives the percentage bare ground as the mean values for each of the treatments imposed. Analysis of variance results (Appendix 9) shows the increased bare ground under the 200 cow days per acre compared to the 120 cow days per acre to be highly significant (p. $<$ 0.001). A significant difference (p $<$ 0.1) due to duration treatments is also indicated.

TABLE XV : Experiment I — Ground cover

		Percent Bare-ground	S.E. Mean	LSD(0.001)	(0.05)
Grazing intensity	120	15.2	1.19	7.72	
(cow days/acre)	200	26.8			
Grazing duration	6	18.2			
(hours)	24	21.3	1.90		4.60
	72	23.5			

The '6 hour' treatment has less bare-ground than both the '72 hour' and '24 hour' treatments; the difference significant at the 5% level in the former comparison and only reaching significance at the 10% level in the latter.

3.1.8   Evenness of grazing

Herbage rejection above the average grazing height for each treatment is given in Figure 11 and data, analysis of variance and t-test results in Appendix 10. Analysis of variance results show there to be significantly more rejection ($p < 0.01$) at the lower grazing intensity and also a significant difference ($p < 0.1$) due to grazing duration. Most rejection occurred in the '6 hour' grazing duration (Figure 11) and a t-test showed the difference in rejection between the '6 hour' and '24 hour' treatments to be significant ($p < 0.05$). The difference between '6 hour' and '72 hour' treatments just failed to reach significance at the 10% level.

3.1.9   Soil Moisture

At no stage throughout the experiment were there any significant differences between treatments in soil moisture content. Individual data and analysis of variance for each sample date are not therefore presented. Figure 12 shows the mean soil moisture content of all plots throughout the experimental period.
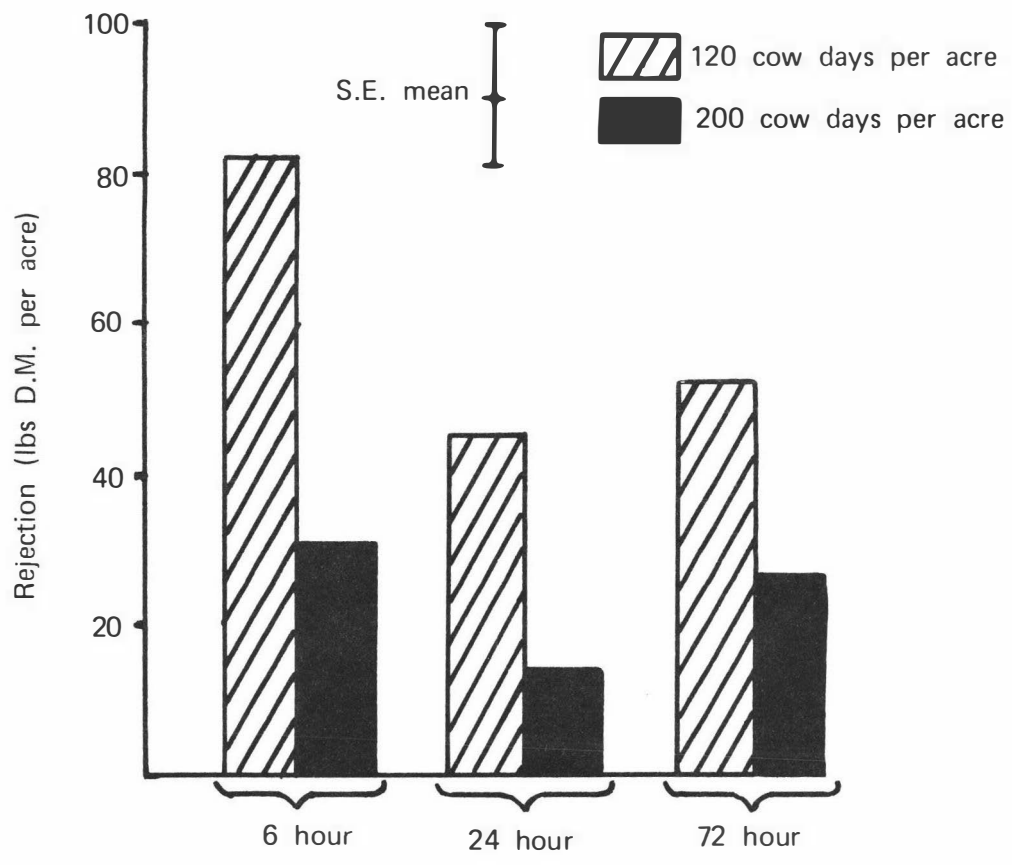
Figure 11 — Experiment I — The effect of grazing intensity and grazing duration on herbage rejection.
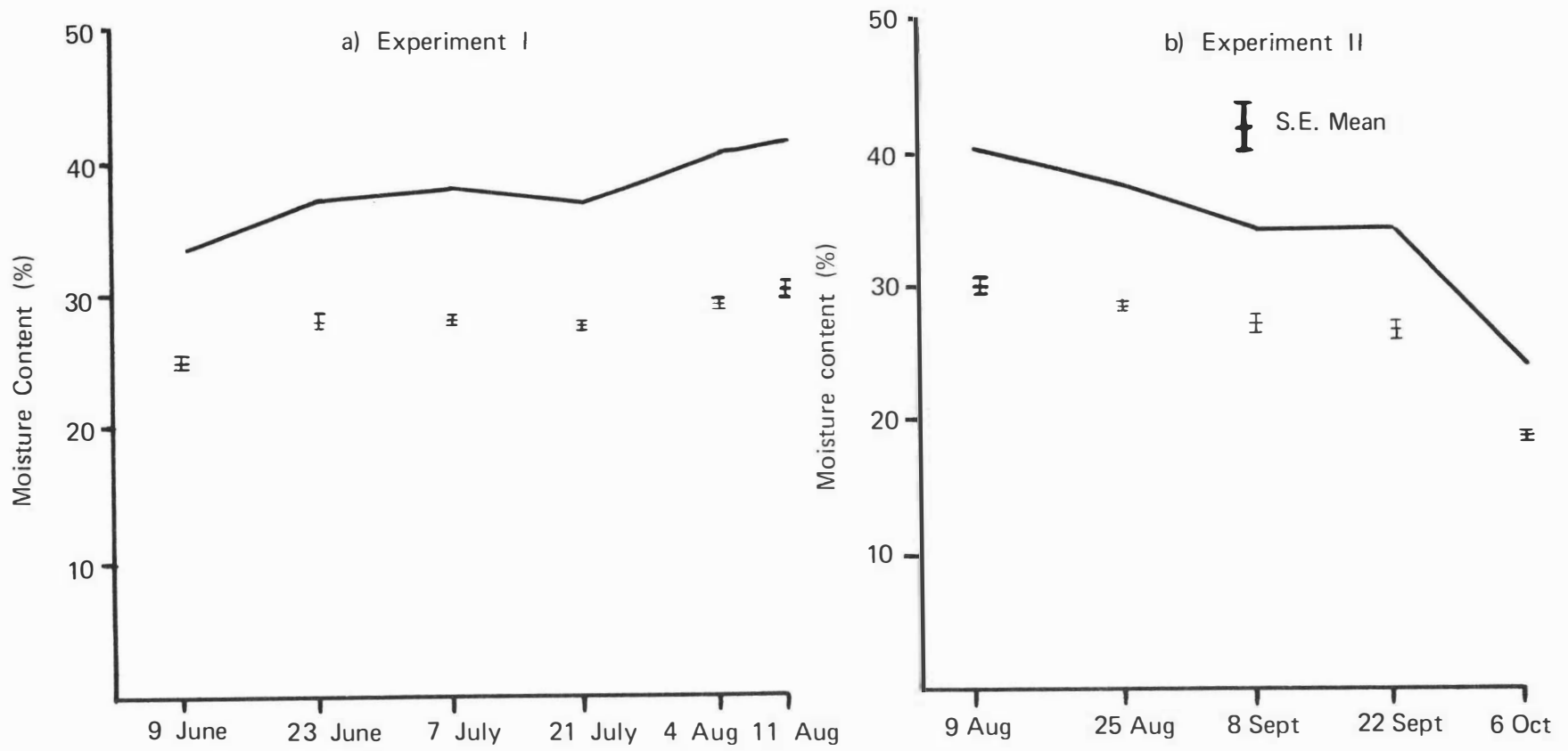
Figure 12 — Experiment I and II — Soil moisture, mean value of all grazed plots

3.1.10 Soil Bulk Density

Analysis of variance (Appendix 11) showed no significant treatments effects at any of the soil layers tested or for the overall 0 - 9 cm depth. Results are therefore presented as the mean values over all treatments for each level measured (Table XVI). Data and analysis of variance results appear in Appendix 10.

TABLE XVI : Experiment I - Soil Bulk density

Soil layer	Density (gm/cc)	S.E.Mean ±
0 - 3 cm	0.809	0.0079
3 - 6 "	0.967	0.0001
6 - 9 "	1.066	0.0067
0 - 9 "	0.948	0.0058

There was however a significant difference between Replicates (Reps) $(p < 0.05)$ at the 0 - 3 cm and 6 - 9 cm levels. t-tests (Appendix 11) show in the top 3 cm, plots in Rep. 2 have significantly lower bulk densities than those in Rep. 1 $(p < 0.01)$ and Rep. 2 $(p < 0.05)$. In the 6 - 9 cm level Rep. 3 has significantly lower bulk density than Rep. 2 $(p < 0.001)$ and Rep. 1 $(p < 0.05)$.

TABLE XVII : Experiment I - Soil Bulk density means
between replicates (gm/cc).

Replicate	0–3 cm	3–6 cm	6–9 cm	0–9 cm
1	0.819	0.983	1.072	0.958
2	0.774	0.973	1.093	0.948
3	0.834	0.944	1.032	0.936
LSD (0.05)	0.043	0.039	0.037	0.100

3.2   Between Days

No significant differences were obtained in DM utilization,
DM production, botanical analysis, soil moisture percentage or
soil bulk density between days within either the '6 hour' or
'24 hour' durations at the two grazing intensities studied.
Several isolated significant interactions were obtained in soil
moisture percentages and DM production but on graphing and t-test
analysis no trends resulted and interactions appeared meaningless.
No data, analysis of variance or t-test results will therefore
be presented. The mean values over three day grazing periods
for all measurements are presented in Section 3.1.

3.3   Control (cut) v's grazed

Heavy and light cutting intensities are termed 200 and
120 cow days per acre equivalent treatments respectively, as
these are the levels of defoliation it was attempted to simulate

with the cutting treatments. In each section comparisons
between the mean cutting and grazing effects over both
defoliation intensities will be dealt with, followed by a
comparison of cutting v's grazing within each of the defoliation
intensity levels.

3.3.1 D.M. Production

Table XVIII presents the overall treatment means,
differences and LSD values while the data appears in Appendix
6-1 and analysis of variance results in Appendix 6-2. Results
are presented in Figure 13 for defoliation treatments at the
two grazing intensities. As no post-grazing control measurements
were taken in Experiment I the analysis starts at day 10.

TABLE XVIII : Experiment I - Defoliation treatment effects
on D.M. production (lb D.M./acre)

Defoliation treatment	Harvest (days from grazing)					
	10	20	30	40	50	60
Cut	813	1047	1171	1261	1321	1919
Grazed	639	745	850	1127	1383	1674
Cut-grazed	174	302	321	134	-62	245
LSD (0.05)	85.5	56.3	66.4	100.5	83.6	232.5
(0.001)	164.9	108.6	128.1	193.9	161.3	448.7

Defoliation method (cutting v's grazing) produced
highly significant effects on DM production $(p < 0.001)$ on
days 10, 20 and 30 and significant effects $(p < 0.05)$ on days
40 and 60. In all cases cut treatments produced more DM per
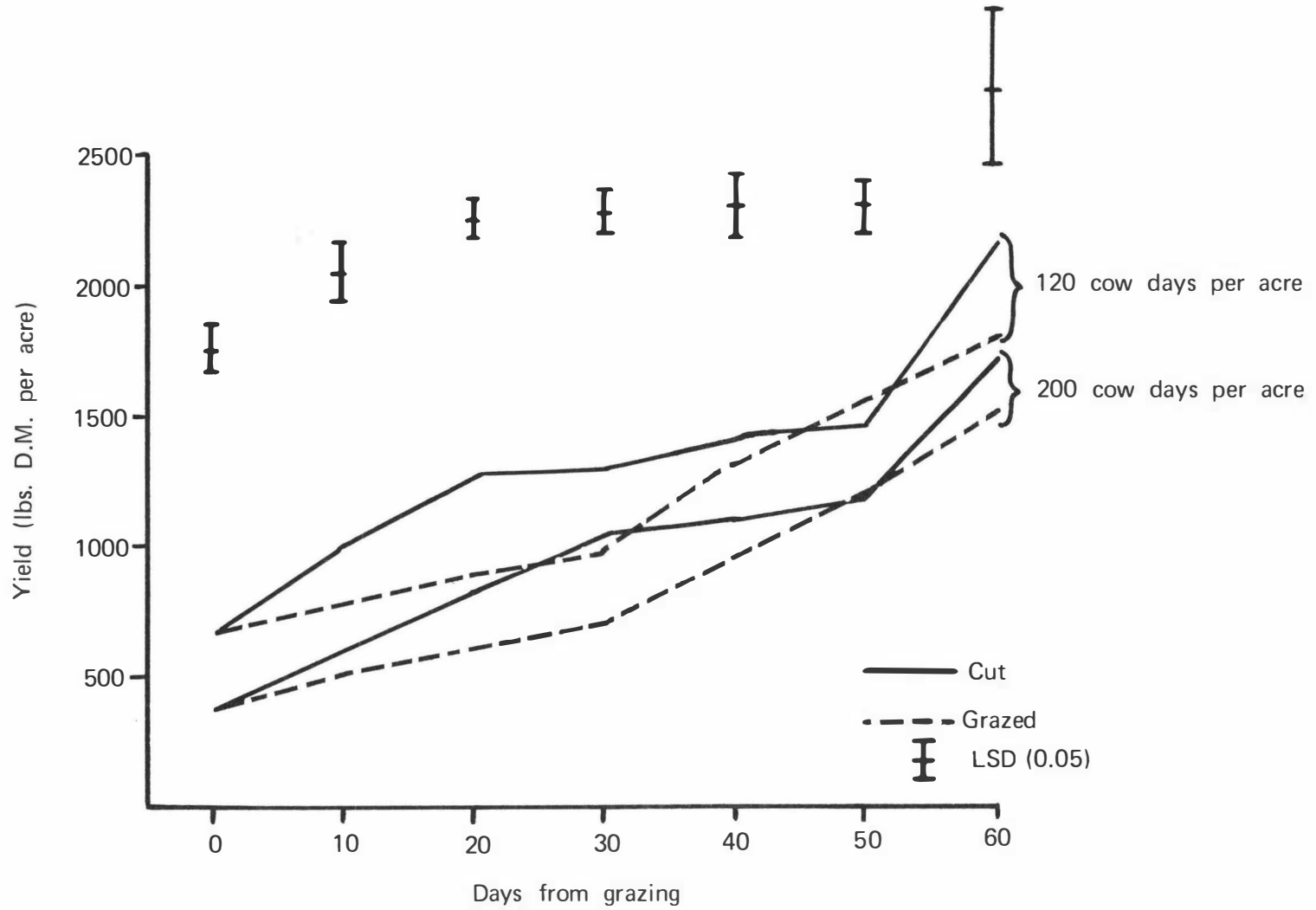
Figure 13 — Experiment I — Defoliation treatment effects on D.M. production.

acre than treatments involving grazing (Table XVIII) except
on day 50 where there was a non-significant decrease on the
control treatments. The trend between cut v's grazed was
similar (Figure 13) within each of the defoliation intensities.
At day 10 and 20 the difference in DM production between plots
cut and those grazed were more pronounced in the 120 cow days
per acre intensity than in the 200 cow days per acre (Table
XIX). This difference between defoliation intensities gave
rise to the significant intensity x defoliation treatment
interactions shown by analysis of variance (Appendix 6-2)
at day 10 $(p < 0.1)$ at day 20 $(p < 0.05)$.

TABLE XIX : Experiment I - Difference between plots cut
             and those grazed at different defoliation
             intensities. (lb D.M./acre)

Cut-grazed	Harvest (days from grazing)					
	10	20	30	40	50	60
'120 cow days/acre'	245	377	316	120	-103	307
'200 cow days/acre'	103	227	325	149	-23	184
LSD (0.05)	120.8	79.6	93.8	142.0	118.3	297.8
(0.001)	233.2	153.5	181.1	274.2	228.3	574.8

3.3.2   Relative Growth Rates

The regressions of log DM with time from day 10 to day 60
for cut and grazed plots are shown in Table XX. Analysis of
variance of the regression coefficients shows a highly significant
$(p < 0.001)$ difference in relative growth rate between cut and

grazed plots. The cut plots in all cases having the lowest coefficients but the highest constants. As shown in Table XX the difference between cut and grazed plots was similar in both defoliation intensities.

TABLE XX : <u>Experiment I - Regression log D.M. with time</u>
<u>for defoliation treatments</u>

Defoliation intensity	Cut			Grazed*	
	Coeff.	SE±	Constant	Coeff.	Constant
120 cow days/acre	0.012	0.002	6.81	0.018	6.41
200 cow days/acre	0.018	0.002	6.32	0.023	5.95
LSD[+] (0.001) (0.05)	0.0058 (0.003)				

+ LSD values for comparison between cut and grazed treatments.

* S.E. not available.

3.3.3 Botanical Composition

The botanical components of DM regrowth for cut and grazed plots (Figure 14) show that unsown grasses increased their contribution to DM production while that of ryegrass and clover was decreased when plots were cut in preference to being grazed. When these components are expressed as percentage contribution (Appendix 12) throughout the regrowth period several points emerge as shown in Figure 15.
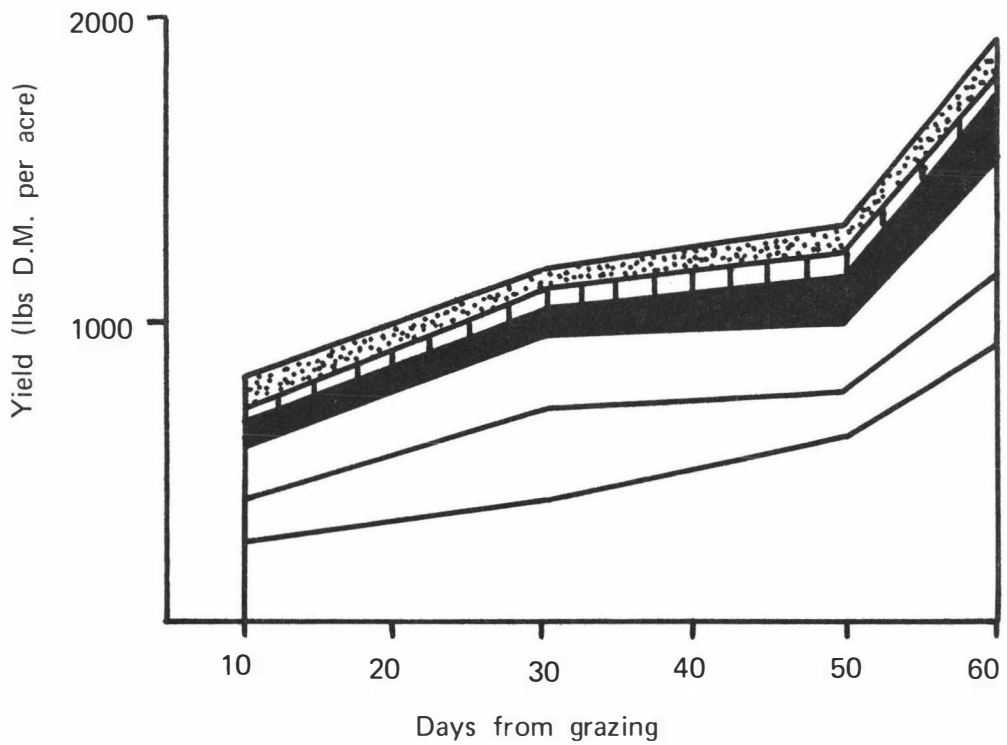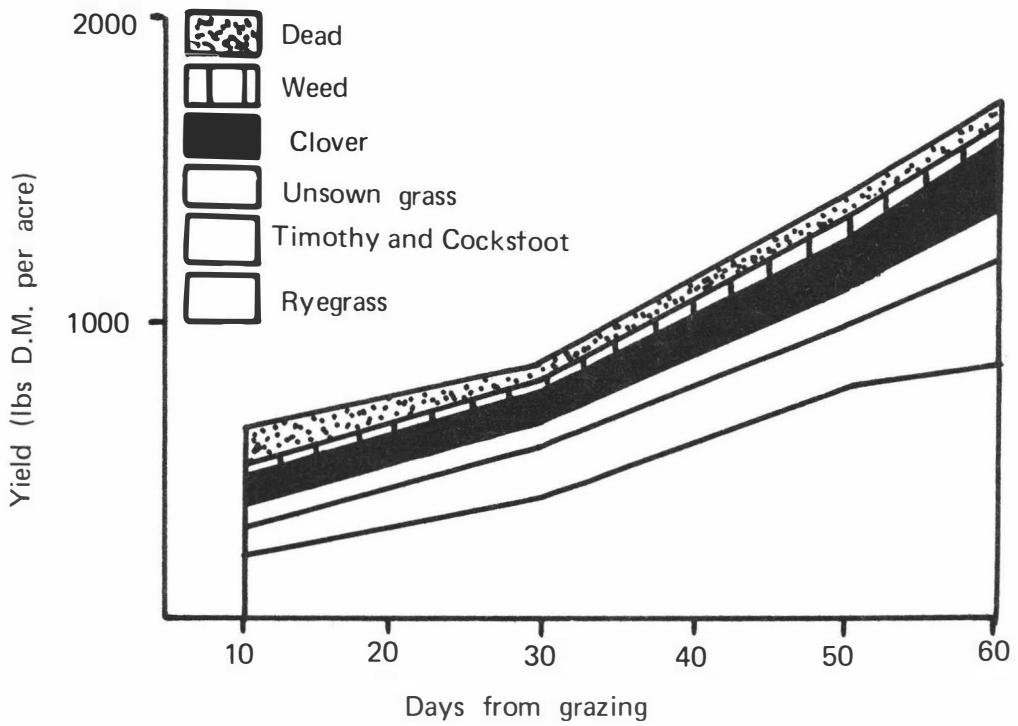
Figure 14 -- Experiment I -- Defoliation treatment effects on D.M. production of botanical components
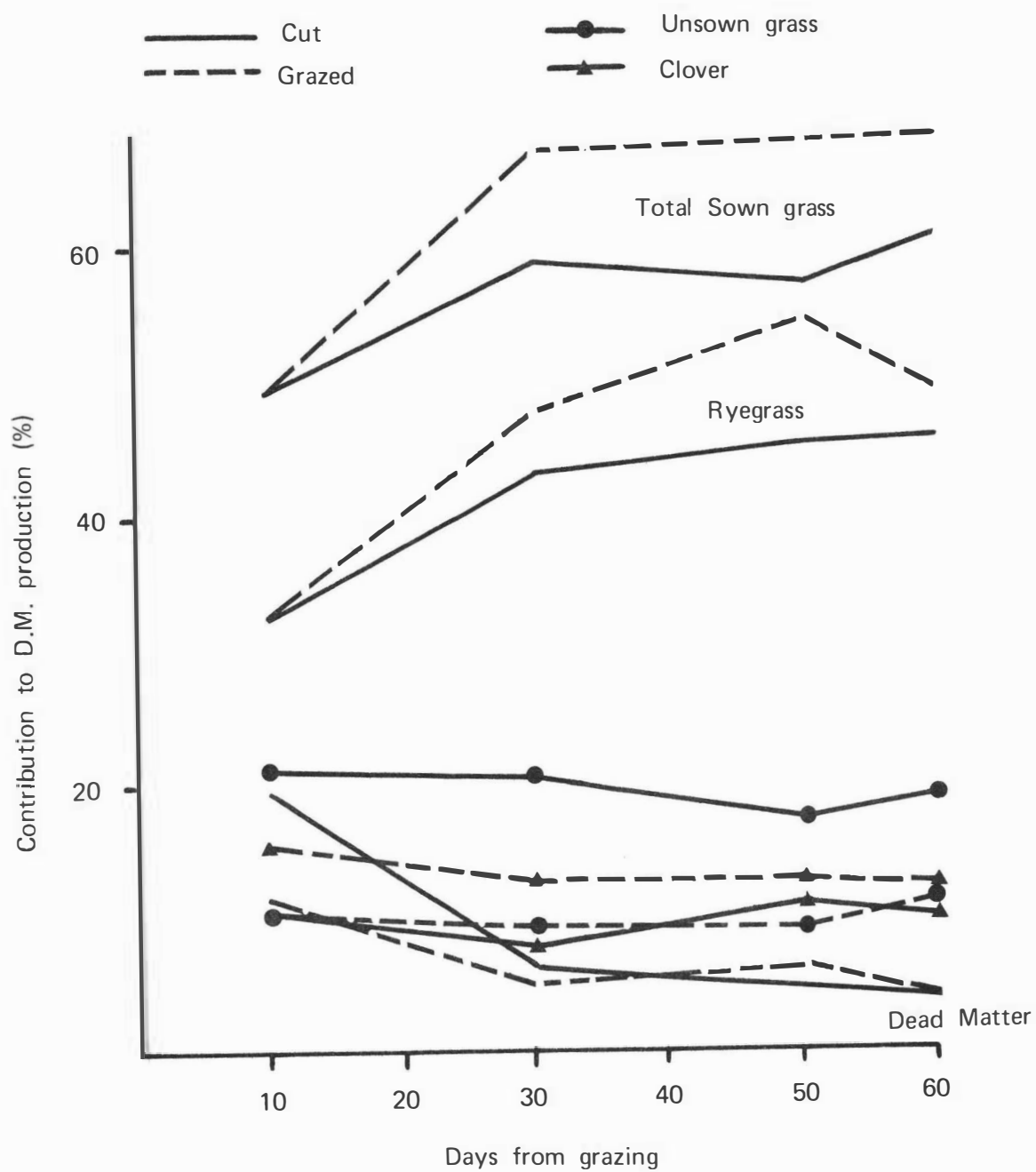
Figure 15 — Experiment I — Defoliation Treatment effects on botanical composition

i Ryegrass appears to be favoured by grazing but the difference in percentage contribution is caused by the increase in unsown grasses on cut treatments rather than an increase in ryegrass DM production on grazed plots.

ii Clover initially appeared favoured by grazing.

iii Unsown grasses gave a larger contribution in cut than in grazed treatments (approximately an increase of 10 percentage units at all sample dates). This increase was due to Poa species as very little 'other grass' was present in any sward.

iv The initial dead matter increase following defoliation is more pronounced in grazed treatments.

Between grazing intensity treatments cut plots showed similar trends in botanical composition to those of grazed plots (Section 3.1.5). In both defoliation treatments the initial dead matter increase following defoliation was greatest at the highest intensity (in the order of 7 percentage units). The lighter defoliation intensity favoured Poa species in both cut and grazed treatments but was more pronounced in the cut treatment. This increase in Poa was 25% in both cut and grazed plots; the relative increase in the cut plots was however greater as these contained approximately 20% Poa species to the grazed plots 10%.

3.3.4 Tiller density

No tiller counts were made on the control plots before grazing so comparisons between cutting and grazing treatments are made only on 19 June, 19 July and 19 August. Data, analysis of variance and t-test information for this section appears in Appendix 13.

Results are presented as mean values over both intensities for each of the defoliation methods in Figures 16 and 17.

Clover : Initially there was a significant decrease with grazing $(p < 0.1)$ after which little difference was apparent between cutting and grazing (Figure 16a).

Total Grass : There was a significantly greater number of total grass tillers per ft^2 in plots cut rather than grazed (Figure 16a), the difference being highly significant at all sample dates (19 June, $p < 0.001$; 19 July and 19 August $p < 0.01$). It is obvious from Figure 16b that these differences originate from the unsown grass species in the sward.

Sown Grass Species : Total sown grass tiller densities show little difference between cutting and grazing until 19 August when cut plots have 17% more tillers per ft^2 than grazed plots. (Figure 16b). The difference however was only significant at the 10% level. The component species show a similar lack of reaction to cutting v's grazing, but as shown in Figure 20a timothy and ryegrass species act in opposite directions.

Unsown Grass Species : At all sample dates there was significantly more unsown grass species tillers per ft^2 in plots that had been cut rather than grazed, due to the
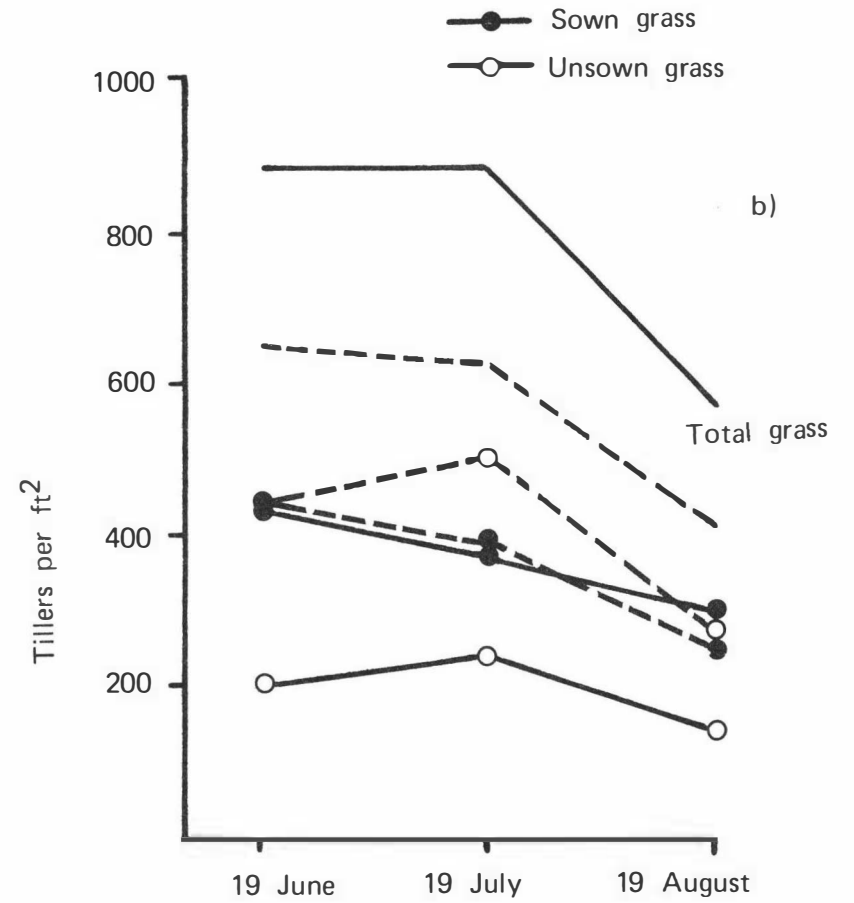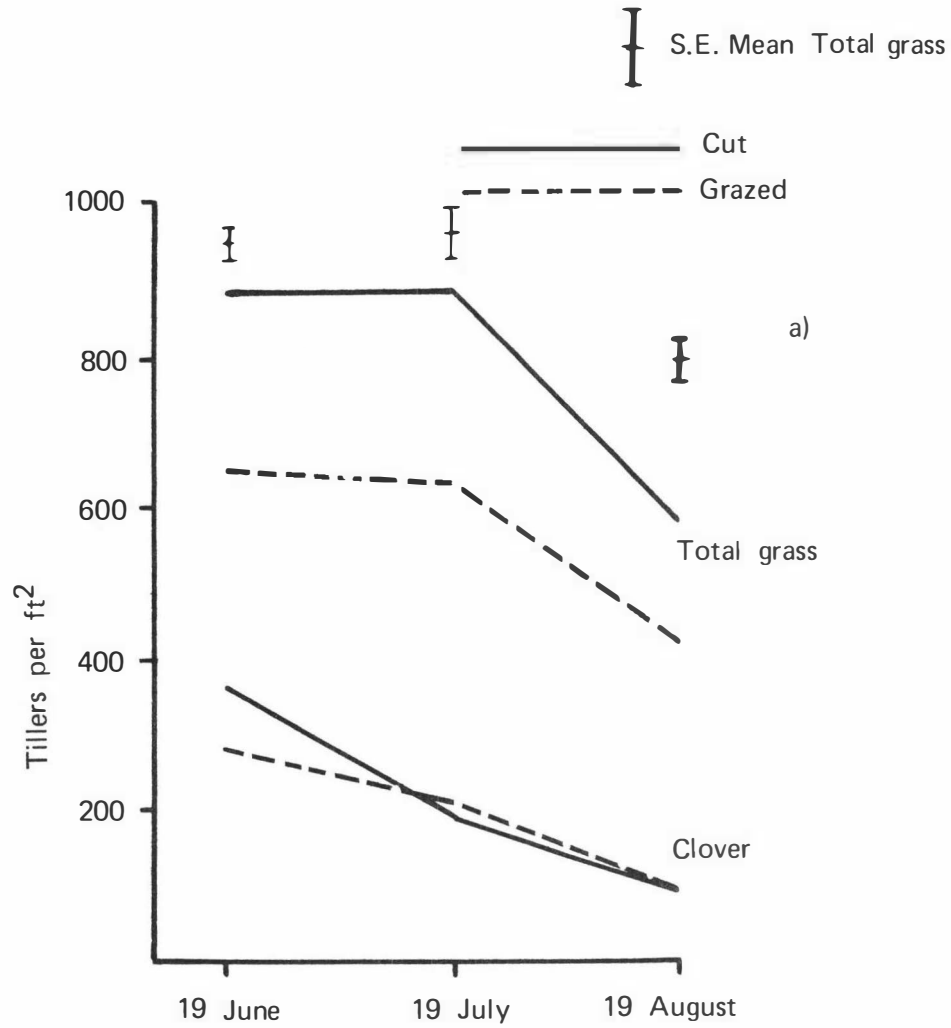
Figure 16 — Experiment I — Defoliation treatment effects on tiller populations
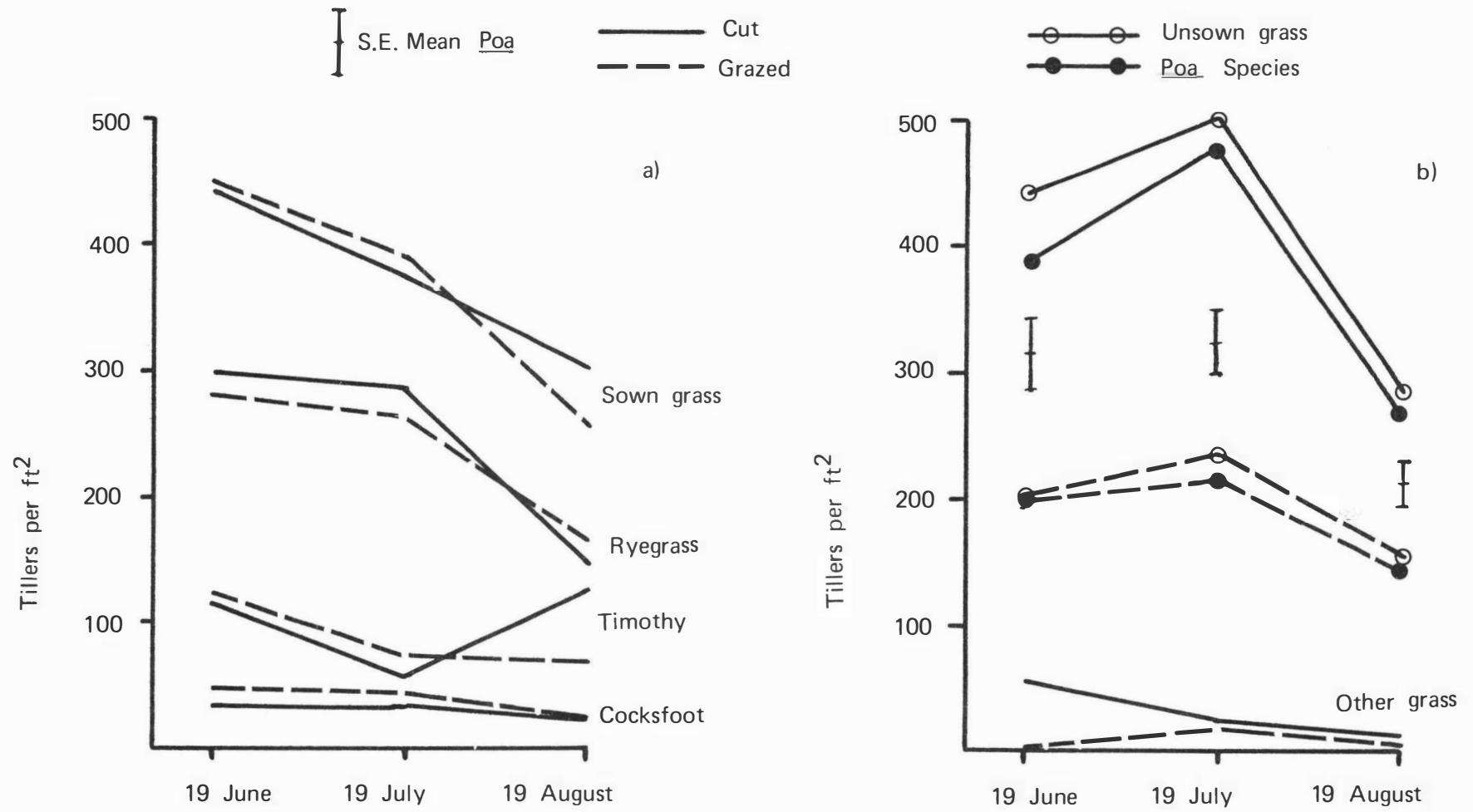
Figure 17 — Experiment I — Defoliation treatment effects on tiller populations

great increase in <u>Poa</u> species in the cut plots (Figure 17b).
The levels of significance reached were similar for both total
unsown grass tillers and <u>Poa</u> species (19 June, $p < 0.01$;
19 July, $p < 0.001$;   19 August, $p < 0.01$).   Initially there
were also more 'other grasses' in the cut plots.

        Within defoliation intensity the reaction of cut v's
grazed paralleled that of the mean values discussed above in
all comparisons except for ryegrass and timothy.   Results
within defoliation intensity were variable for both species
(Table XXI).   Analysis of variance (Appendix 13) shows a
significant defoliation intensity x defoliation treatment
effect $(p < 0.05)$ at the second sample (19 July) in both the
ryegrass and timothy components which are due to the cut v's
grazed effect being significant at the low intensity only
$(p < 0.05)$.   Ryegrass had a 20% increase in tillers with
cutting and timothy a 58% decrease.   By the final sample
(19 August) the decrease in timothy tillers per ft^2, in
grazed compared with cut plots at the 200 cow days per acre
intensity had reached significance at the 5% level.

3.3.5   Ground Cover

        Analysis of variance of ground cover data (Appendix 14)
shows the increase in bare ground when plots are grazed in
preference to cut (Table XXII) to be highly significant
$(p < 0.001)$.   A significant interaction between defoliation
intensity and defoliation treatment $(p < 0.1)$ is shown by t-test
to be due to the difference between grazing and cutting on the
percentage bare ground to be greater at 200 cow days per acre
$(p < 0.01)$ than at 120 cow days per acre $(p < 0.05)$(Table XXII).

TABLE XXI : Experiment I – The effect of defoliation treatment on ryegrass and timothy tiller populations

	Date	120 cow days per acre			200 cow days per acre			LSD 0.05
		grazed	cut	grazed-cut	grazed	cut	grazed-cut	
Ryegrass	19 June	306	272	34	257	325	-68	99.1
	19 July	300	360	-60	238	217	21	55.4
	19 August	142	168	-26	182	144	38	76.0
Timothy	19 June	141	125	16	103	96	7	61.7
	19 July	78	32	45	74	85	-11	31.2
	19 August	70	115	-45	72	136	-64	57.2

TABLE XXII : Experiment I – The effect of defoliation treatment on ground cover (% bare ground)

Treatment	Mean	120 cow days/acre	200 cow days/acre
grazed	21.2	15.3	27.0
cut	9.7	6.7	12.7
S.E. mean ±	0.83	1.18	
LSD (0.05)		6.75	
(0.001)	6.99		

3.3.6   Soil Moisture

Soil moisture figures are presented for control and
for grazed treatments in Figure 18b. Individual plot data and
analysis of variance for each sampling date appear in Appendix 15.

No individual soil moisture determinations were made
on the control plots on the 9 June (pre-grazing) as it was
assumed the overall mean for all plots within the paddock would
represent that for all plots including the controls. As shown
in Figure 18b the grazed plots had consistently lower soil moisture
values than the cut plots. Analysis of variance showed this
difference to be significant on 23 June $(p < 0.01)$ and 21 July
$(p < 0.05)$. Cutting and grazing treatments had similar effects
within each defoliation intensity treatment and when graphed
simply reflected the mean cut and grazed values (Figure 18b).
The greatest difference between defoliation intensities in soil
moisture was only 1.2 percentage units on 23 June (Figure 18a).
Although small, this difference reached significance at the 5%
level.

3.3.7   Soil Bulk Density

Control samples for bulk density determination were
not taken from the cut areas but from areas of undisturbed
pasture. In the analysis of variance the control v's grazed
mean square was tested against the Rep x cutting treatment
interaction. Differences between treatments in soil bulk
densities were small (Table XXIII). Analysis of variance
(Appendix 16) shows there to be a significant $(p < 0.1)$
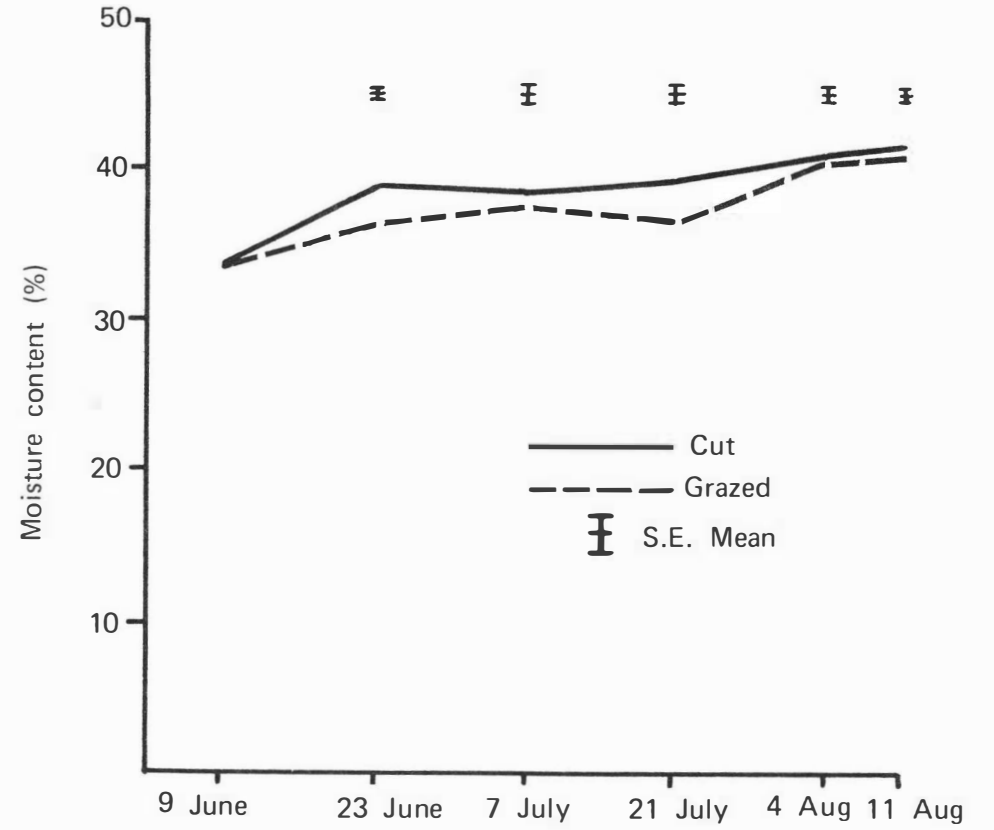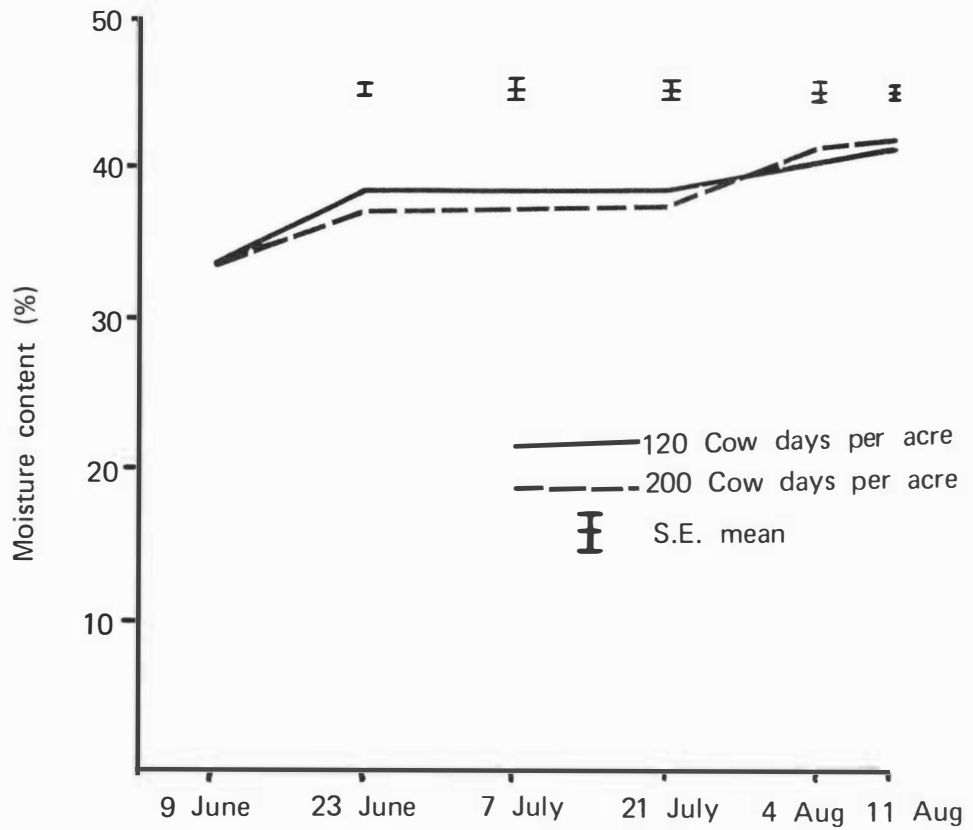
Figure 18 — Experiment I -- Defoliation treatment effects on soil moisture

treatment effect in the 6 - 9 cm layer where the grazed plots have a higher bulk density than those not grazed, though the difference is small (0.037 gm/cc).

TABLE XXIII : Experiment I - Defoliation treatment effect upon Soil bulk density (gm/cc)

	Soil layer (cm)			
	0 - 3	3 - 6	6 - 9	0 - 9
Grazed	0.809	0.967	1.066	0.947
cut	0.808	0.852	1.029	0.897
grazed-cut	0.001	0.115	0.037	0.050
LSD (0.05)	0.132	0.461	0.046	0.186
SE Mean ±	0.022	0.076	0.008	0.031

CHAPTER IV

RESULTS — EXPERIMENT II

4.1 Grazing intensity v's grazing duration

4.1.1 Cow Weights

The mean weight of the nine cows allocated to each experimental treatment are presented in Table XXIV and data and analysis of variance in Appendix 4.

TABLE XXIV : Experiment II — Cow weights (lbs liveweight)

| | | Grazing Intensity (Cow days/acre) | |
		120	200
Grazing	6	808.3	802.6
Durations	24	805.1	821.5
(hours)	72	809.9	798.7
S.E. Mean ±		11.75	

The analysis of variance indicated no significant differences in the average weight of cows between experimental treatments but it did show a significant difference ($p < 0.05$) due to allocation between replicates. On average the cows allocated to Rep. 1 were 25 lb and 34 lb lighter than those allocated to Rep 3 and Rep 2 respectively; these differences being shown to be significant at the 10% level for the smaller weight difference and at the 5% level for the 34 lb weight difference.

4.1.2   D.M. Utilization and Intake

The average intake per cow per day during Experiment II was 6.60 ± 0.25 lb D.M.   Daily intake per cow and percentage utilisation results for each grazing intensity and duration are presented in Table XXV.   Data and analysis of variance information appears in Appendix 17.

TABLE XXV :   Experiment II - Daily D.M. intake and
            percentage utilization

		Intake (lbs D.M./cow/day	Percent Utilization
Grazing intensity (Cow days/acre)	120	8.54	63.7
	200	4.67	60.8
S.E. Mean ±		0.352	2.34
LSD (0.05)		1.134	8.54
Grazing duration (hours)	6	5.85	58.4
	24	7.41	65.6
	72	6.55	62.8
S.E. Mean ±		0.431	2.86
LSD (0.05)		1.39	10.46

The 45.3% reduction in intake per cow per day with the increase in grazing intensity from 120 to 200 cow days per acre was highly significant ($p < 0.001$). Analysis of variance also showed a significant ($p < 0.1$) duration effect which is shown by t-test to be due to the cows on the '24 hour' treatments having a significantly ($p < 0.05$) higher DM intake than those on the '6 hour' treatment.

Difference in percentage utilization between treatments were non significant, the greatest difference present was that between the '6 hour' and '24 hour' durations of 7.2 percentage units.

4.1.3   D.M. Production

Results for each grazing duration at the two grazing intensities studied are presented in Figure 19. The mean values for grazing intensity and grazing duration effects are given in Table XXVI with data, analysis of variance and t-test results in Appendix 18-1, 18-2 and 18-3 respectively.

Analysis of variance of comparisons over the three durations and two grazing intensities were analysed in a combined analysis with grazing techniques, as had also been done in Experiment I.

Significant results shown by analysis of variance of DM data for each harvest are summarised in Table XXVII. t-test results show that the significant grazing duration effect in the pre-grazing harvest is due to the '24 hour' treatment having significantly more DM per acre than the '6 hour' treatment $(p < 0.05)$.

The difference amounted to 226 lb DM per acre or expressed as a percentage the cows on the '24 hour' treatments had 15.6% more DM available to them than those on the '6 hour' treatment.

TABLE XXVI : <u>Experiment II - D.M. Production (lbs D.M./acre)</u>

| | | Pre- | Post- | Harvest (days from grazing) | | | | |
				10	20	30	40	50
Grazing intensity	120	1602	576.3	596.4	1007	1485	2140	3097
(cow days/acre)	200	1516	582.0	476.1	805.4	1195	1733	2495
Diff. 120 - 200		86	-5.7	120.3	201.6	290	407	602
LSD (0.001)		331.0	127.2	95.6	149.4	199.7	389.4	500.1
S.E. Mean ±		46.2	21.7	16.3	25.5	34.1	66.6	85.4
Grazing durations	6	1445	592.7	621.8	993.2	1384	1947	2787
(hours)	24	1671	566.3	491.3	854.8	1248	1872	2821
	72	1560	578.5	495.7	871.0	1388	1991	2781
LSD (0.05)		171.5	80.7	60.7	94.8	120.5	247.1	314.9
S.E. Mean ±		56.6	26.6	20.0	31.2	41.8	81.5	104.6

TABLE XXVII : Experiment II – D.M. Production, Significant results due to grazing intensity and grazing duration.

	Pre-	Harvest (days from grazing)					
		Post	10	20	30	40	50
Grazing intensity	n.s.	*	***	***	***	***	***
Grazing duration	*	n.s.	***	*	+	n.s.	n.s.
Interaction	n.s.	n.s.	**	**	***	n.s.	+
Replicate	*	*	*	n.s.	n.s.	+	+

TABLE XXVIII : Experiment II – Difference in D.M. production (lbs/acre) between grazing intensities (120 cow days per acre – 200 cow days per acre).

		Harvest (days from grazing)					
		Post	10	20	30	40	50
Grazing	6	20.7	121.7**	234.3**	294**	325*	594*
duration	24	62.0	233.3***	377.0***	576***	681***	1007***
(hours)	72	-99.6+	6.0	-6.0	0	213	202
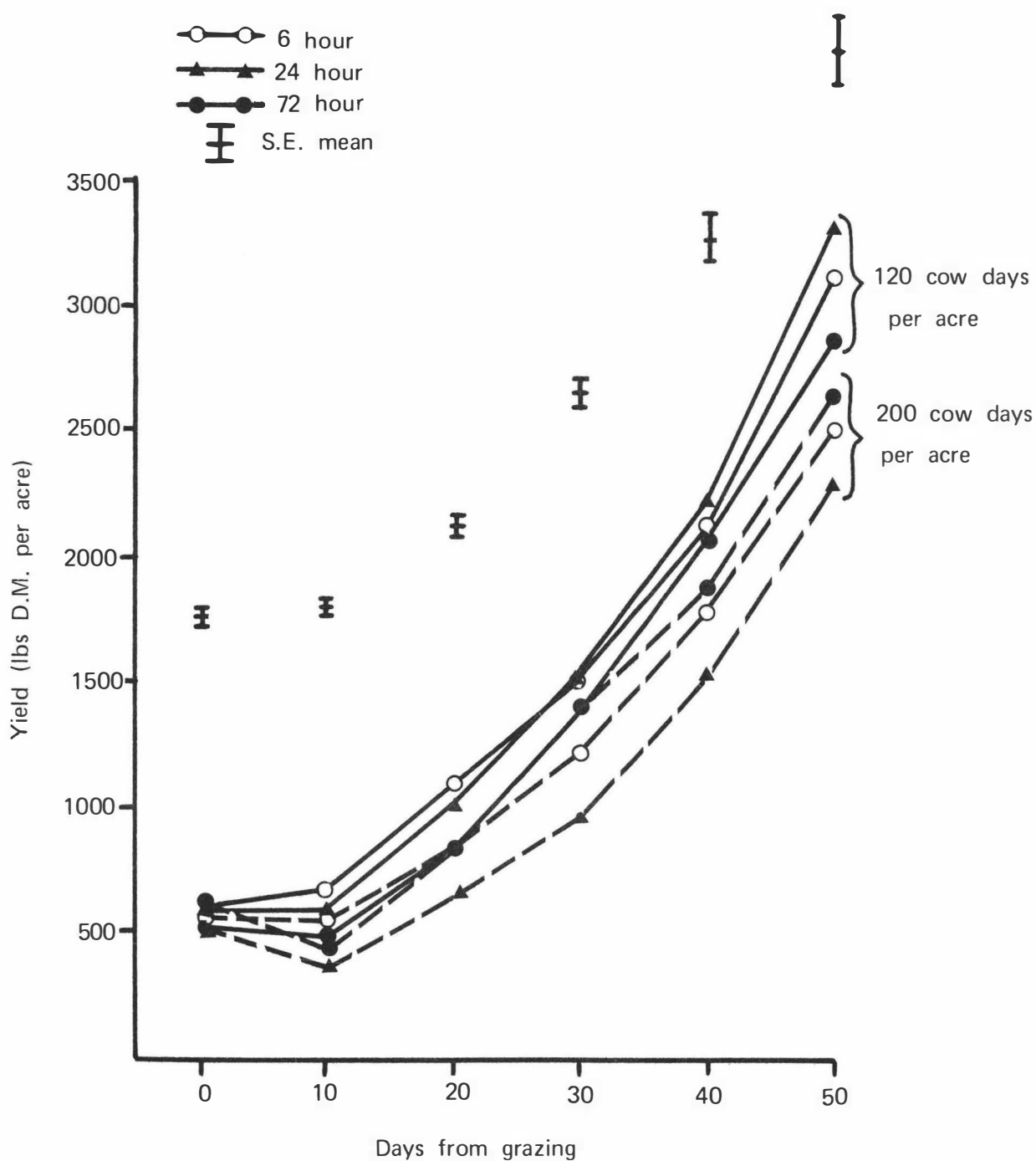
Figure 19 -- Experiment II — The effect of grazing duration and grazing intensity on

D.M. production

Grazing Intensity

Table XXVII indicates highly significant ($p < 0.001$) grazing intensity effects at all regrowth harvests but not the post-grazing harvest. The significant difference in the post-grazing harvest is due to the cut plots only (Section 4.3.1), the difference of 5.7 lb DM per acre between the grazing intensity treatments is non-significant.

The different response in DM production between 120 and 200 cow days per acre intensities within each of the three durations studied gives rise to intensity x duration interactions at harvests from days 10, 20, 30 and 50. This interaction is shown graphically in Figure 19 and the differences between intensities within grazing durations are presented in Table XXVIII with the levels of significance reached for each comparison. The higher grazing intensity is shown to cause a highly significant reduction in DM ($p < 0.001$) in the '24 hour' duration treatment throughout the regrowth period; to be highly significant in the '6 hour' treatment early in the regrowth period; and to have no significant effect in the '72 hour' treatment at any time during the regrowth period.

Grazing Duration

As a result of the interaction between grazing intensity and grazing duration at most harvest dates, grazing durations will be studied within grazing intensities. In each grazing intensity there was one grazing duration treatment inferior to both the other treatments. Figure 19 shows this to be the

'72 hour' duration at the lowest intensity and the '24 hour'
duration at the highest; Table XXIX gives the reduction in
D.M. per acre of these two treatments from the other durations
studied, with the level of significance reached for each
comparison.

The comparisons presented in Table XXIX tend to lose
statistical significance as regrowth proceeds. Significant
differences between grazing durations, other than those given
in Table XXIX occurred only twice, when the '6 hour' treatment
produced more DM per acre than the '24 hour' treatment ($p < 0.1$)
at the low grazing intensity on day 10, and the '72 hour' more
than the '6 hour' ($p < 0.1$) at the high grazing intensity on
day 30.

Replicates

Mean DM per acre figures for each replicate are presented
in Table XXX and t-tests on the significant results shown in
Table XXVII appear in Appendix 18-3.

Prior to grazing plots in Replicate 1 had 514 lb and
303 lb DM per acre more than Replicate 2 and Replicate 3 respectively
($p < 0.001$ in each case). The difference between Replicates 2
and 3 was also highly significant ($p < 0.01$).

The significant results immediately after grazing were
due to significantly lower DM per acre ($p < 0.01$) on Replicate
3 than the remaining two at both post-grazing and day 10 harvests.
Significance at later harvests was caused by the DM in Replicate
3 being greater than Replicate 2 ($p < 0.05$) at day 40 and both
Replicates 1 and 2 ($p < 0.05$) at day 50.

TABLE XXIX : Experiment II - Difference in DM production (lbs/acre) between grazing durations within grazing intensities

Grazing intensity	Comparisons (Durations)	Post-	Harvest (Days from grazing)				
			10	20	30	40	50
120 cow	6 - 72	74	186***	242**	143[+]	11	200
days/acre	24 - 72	68	111**	175*	148[+]	114	440[+]
200 cow	6 - 24	47	186***	210**	277**	253	173
days/acre	72 - 24	93	118**	208**	428***	354[+]	362

TABLE XXX : Experiment II - Mean DM production per Replicate (lb DM per acre)

		Harvest (Days from grazing)						
		Pre-	Post-	10	20	30	40	50
Replicate	1	1966	605	522	1021	1531	1996	2798
	2	1452	621	555	1001	1422	1897	2794
	3	1663	533	491	946	1466	2133	3090
SE Mean ±		49.0	23.1	17.3	27.1	36.2	70.6	90.6
LSD (0.05)		148.6	69.9	52.6	82.1	109.8	214.1	274.8

120 Cow days/acre - 72 hours

200 Cow days/acre - 72 hours

200 Cow days/acre - 24 hours
Day 1

200 Cow days/acre - 24 hours
Day 2

200 Cow days/acre - 24 hours
Day 3

Plate III - Experiment II - Photos taken two days after grazing.

120 cow days/acre - 6 hours   120 cow days/acre - 24 hours

200 cow days/acre - 6 hours   200 cow days/acre - 24 hours

Plate IV - Experiment II - Plots Grazed on Day 1.

Experiment II –

TABLE XXXI : Regression Log D.M. with time for Grazing Duration and Grazing

Intensity treatments

		120 cow days per acre			200 cow days per acre		
		Coeff.	S.E.*	Constant	Coeff.	S.E.*	Constant
Duration	6	0.037	0.002	6.21	0.037	0.001	5.99
(hours)	24	0.042	0.001	6.06	0.046	0.001	5.48
	72	0.043	0.002	5.85	0.041	0.003	5.87

LSD+ (0.001) (0.05)   0.0096   (0.005)

* S.E. are based on the deviations of mean values about
  fitted regressions.

+ LSD values for comparison of coefficients

4.1.4 Relative Growth Rates

Coefficients and constants for the regression of log DM with time for each grazing intensity treatments are presented in Table XXXI. Analysis of variance of the regression coefficients is given in Appendix 18-4.

The analysis showed highly significant ($p < 0.01$) differences in relative growth rate, over the period 10 days to 50 days, between grazing durations. t-tests (Appendix 18-4) show the '6 hour' treatment to have a significantly slower growth rate than both the '24 hour' ($p < 0.001$) and '72 hour' ($p < 0.01$) treatments. Grazing intensity has a much smaller effect on b values in comparison to grazing durations (Table XXXI).

4.1.5 Botanical Composition

Graphing the regrowth of individual treatments in terms of individual components showed no trend in botanical composition between treatments. Figure 20 gives the mean effect over all treatments. The composition of each 100 lb DM for the mean of grazing intensity and grazing durations were calculated at each analysis date (Appendix 19) and those species showing trends due to treatment presented in Figure 21. Total sown grass species reflect directly the changes in ryegrass. Virtually all species showed a relative decline immediately following grazing because of the increased dead material present particularly at the high grazing intensity. Grazing duration appeared to affect the ryegrass and clover components, with the '24 hour' duration treatment encouraging ryegrass at the expense of clover. At no stage however did the differences presented reach major proportions.
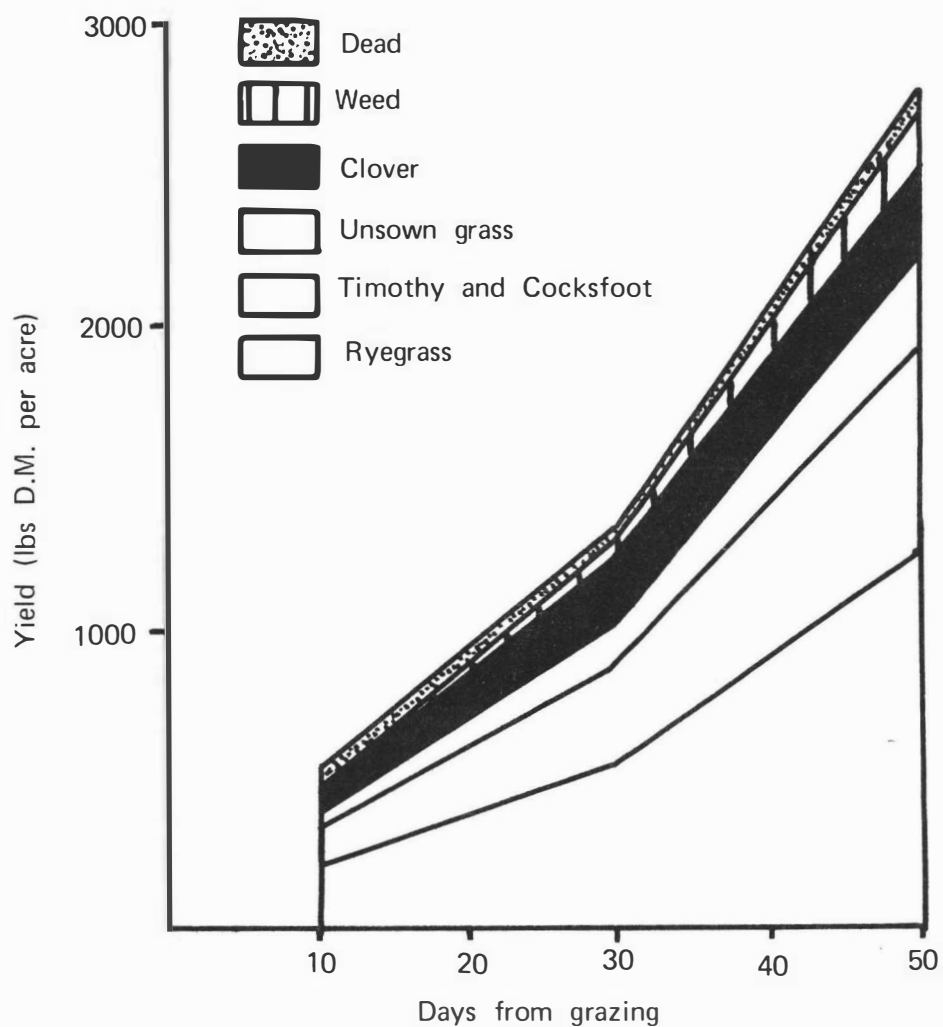
Figure 20 — Experiment II — Botanical components of D.M. Regrowth
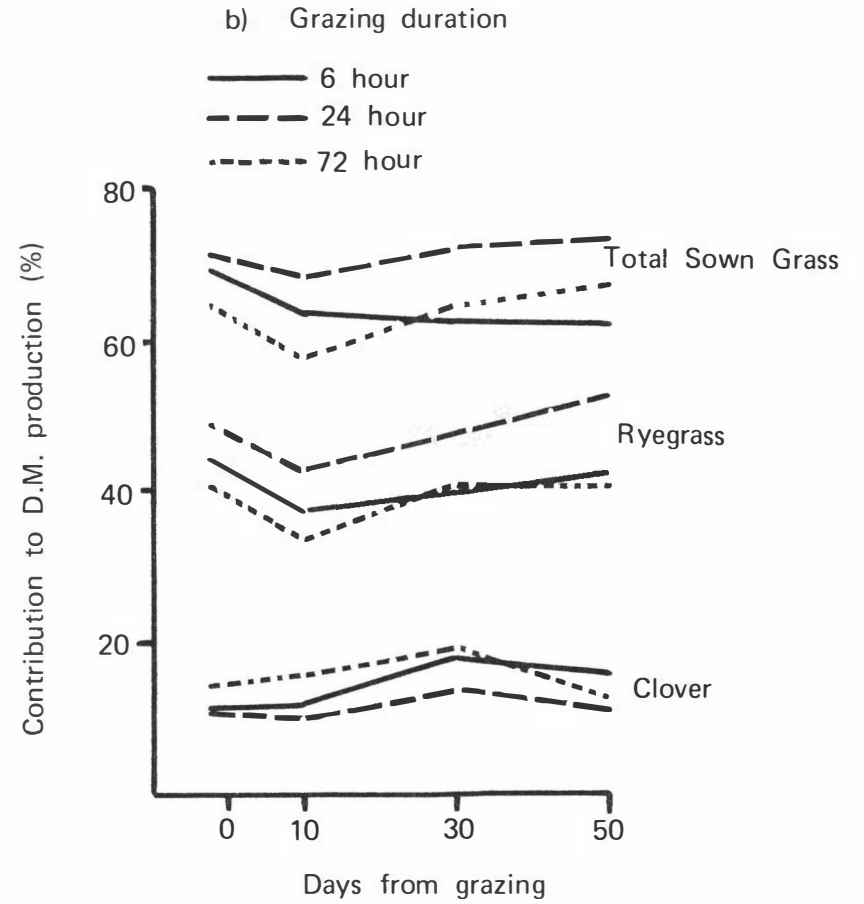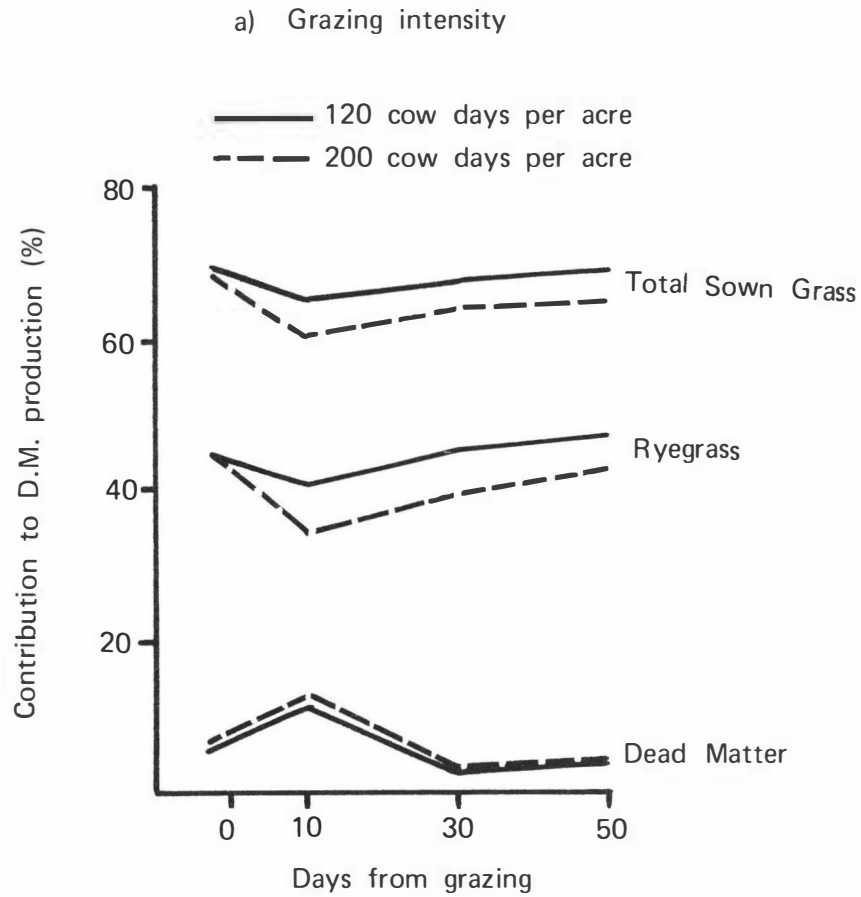
Figure 21 — Experiment II — The effect of grazing intensity and grazing duration on botanical composition

4.1.6   Tiller Density

Analysis of variance (Appendix 20) showed that both grazing intensity and grazing durations frequently affected tiller populations and so individual species will be covered under these treatments.

(i) Grazing Intensity

Clover nodes   :   Clover node populations decreased from 157 ± 8.16 per ft^2 on 8 August to 78 ± 4.9 per ft^2 on 6 October. Grazing intensity had little effect upon this movement (Figure 22 a), with differences between the two intensities being greater on 8 August than at any stage following grazing.

Total Grass tillers : Total grass tiller numbers fell from 538.5 ± 19.4 per ft^2 to 266.4 ± 12.0 per ft^2 over the course of the experiment (Figure 22a). Initial reduction following grazing was greatest in the 200 cow days per acre treatment with the difference of 79.9 tillers per ft^2 between the intensities reaching significance at the 10% level ($p < 0.1$).

Total Sown Grass Species : Total grass tiller populations are on the whole a reflection of those of the sown grass species (Figure 22b). In the sown grass species the reduction in population at the highest grazing intensity was significant on 24 August ($p < 0.05$) and 15 September ($p < 0.1$) when the reduction was 89.2 and 30.4 tillers per ft^2 respectively.
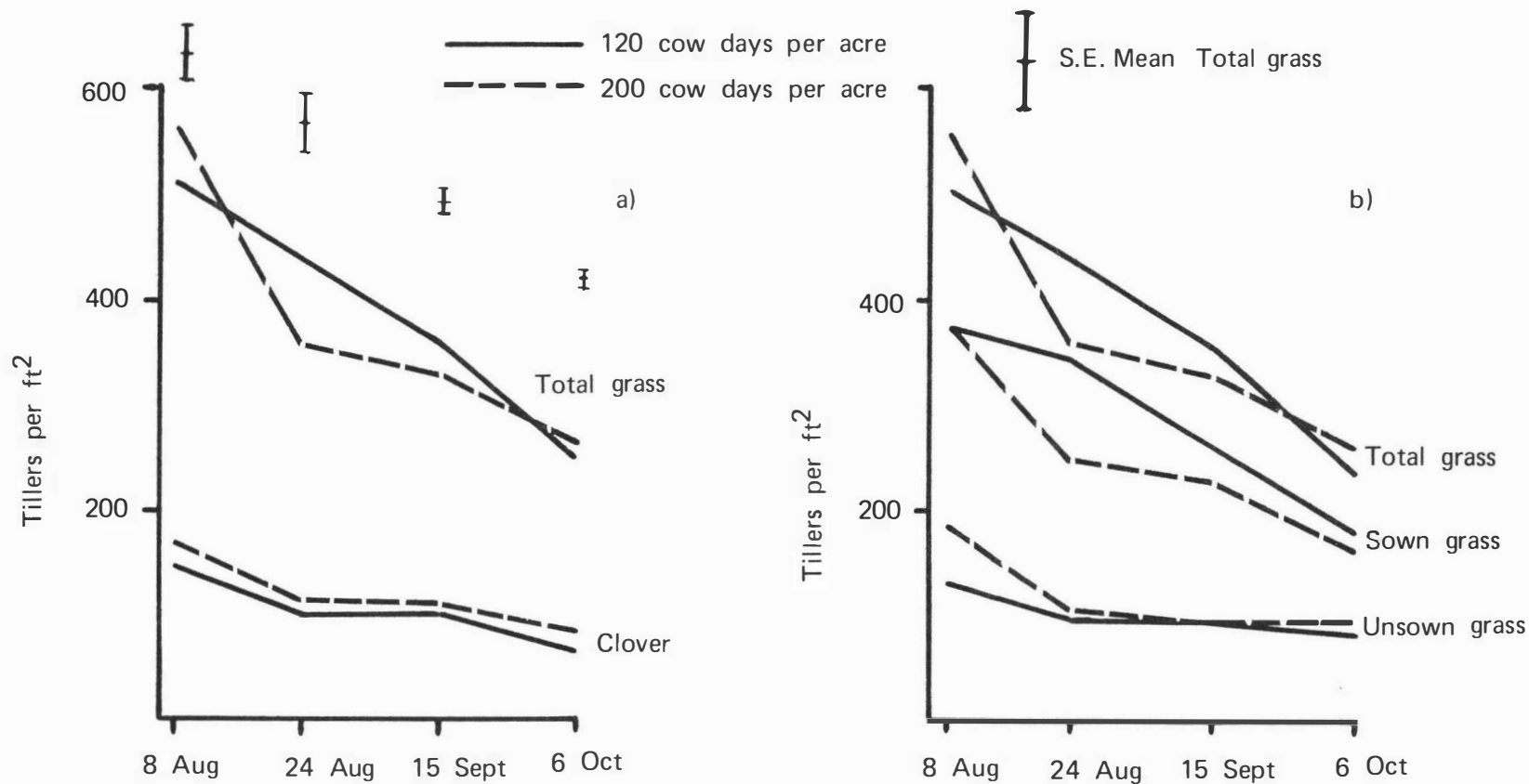
Figure 22 — Experiment II — Grazing intensity effects on tiller populations
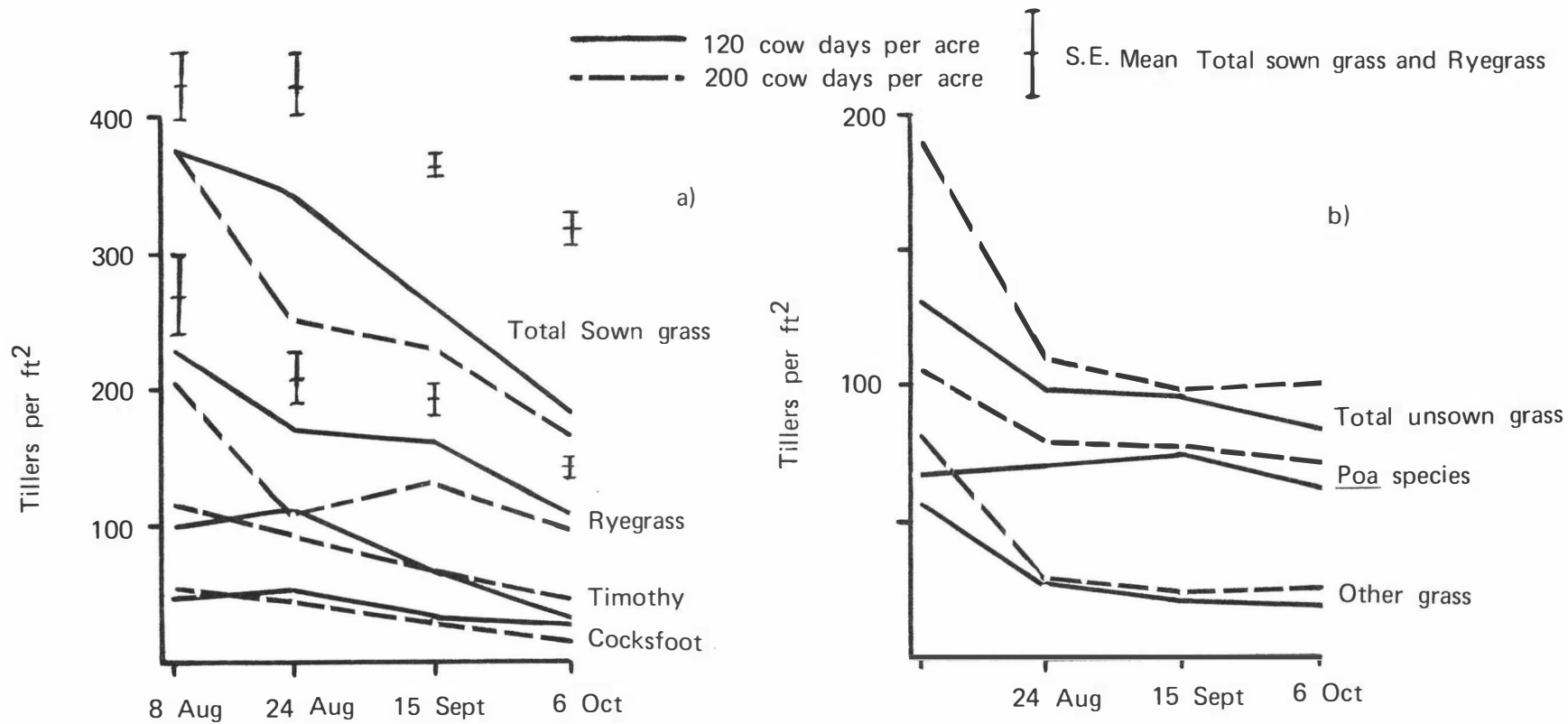
Figure 23 — Experiment II — Grazing intensity effects on tiller populations

Within the component species (Figure 23a), the total is a reflection of the ryegrass component. The difference (64.0 tillers per ft^2) between intensities in the ryegrass component on 24 August approached significance at the 5% level, being significant at the 10% level ($p < 0.1$). Grazing intensity appeared to have no direct influence upon the tiller populations of either timothy or cocksfoot.

Total Unsown Grass Species : Grazing resulted in an immediate reduction in unsown grass tiller populations (Figure 22b). The difference between grazing intensities was confused by significant intensity effects in Poa and total unsown tiller numbers prior to grazing. The 200 cow days per acre treatment having 58.1 total unsown grass and 39.3 Poa tillers more per ft^2 than the 120 cow days per acre treatment. Individual grazing intensities appeared not to have any long term affect upon the unsown grass tiller populations (Figure 23b).

(ii) Grazing Duration

Clover nodes : Following grazing, grazing duration appeared to have a greater effect upon clover densities (Figure 24a) than had grazing intensity (Figure 22a). Clover populations were reduced with grazing at the '24 hour' duration greater than both the '6 hour' and '72 hour' treatments ($p < 0.05$). Over the regrowth period conditions in the '72 hour' treatment favoured clover populations with the '72 hour' duration having significantly more clover nodes per ft^2 on the 15 September than both the '6 hour' and '24 hour' treatments ($p < 0.001$) and on 6 October significantly more than the '24 hour' treatment only ($p < 0.05$).
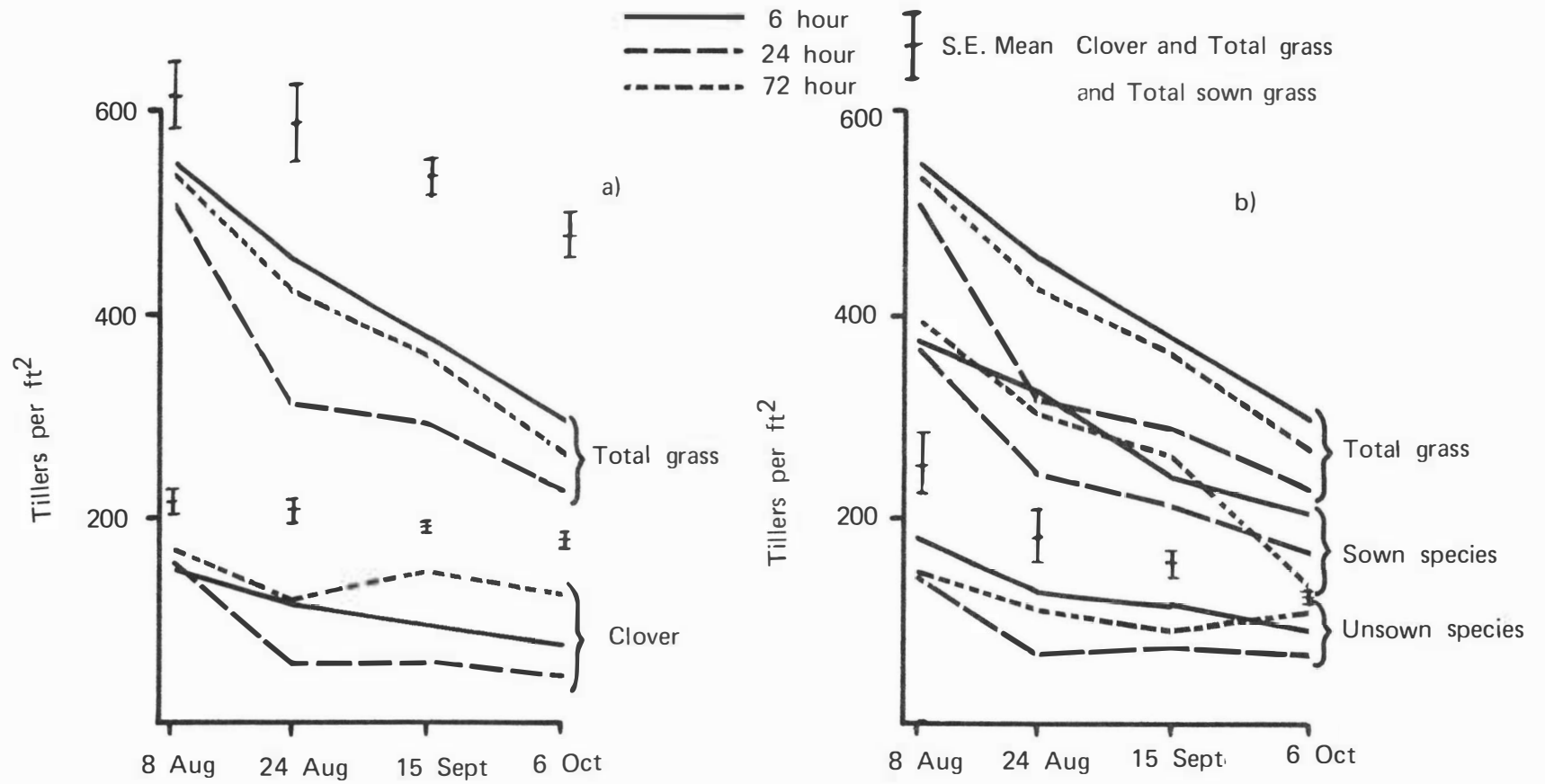
Figure 24 -- Experiment II — Grazing duration effects on tiller populations
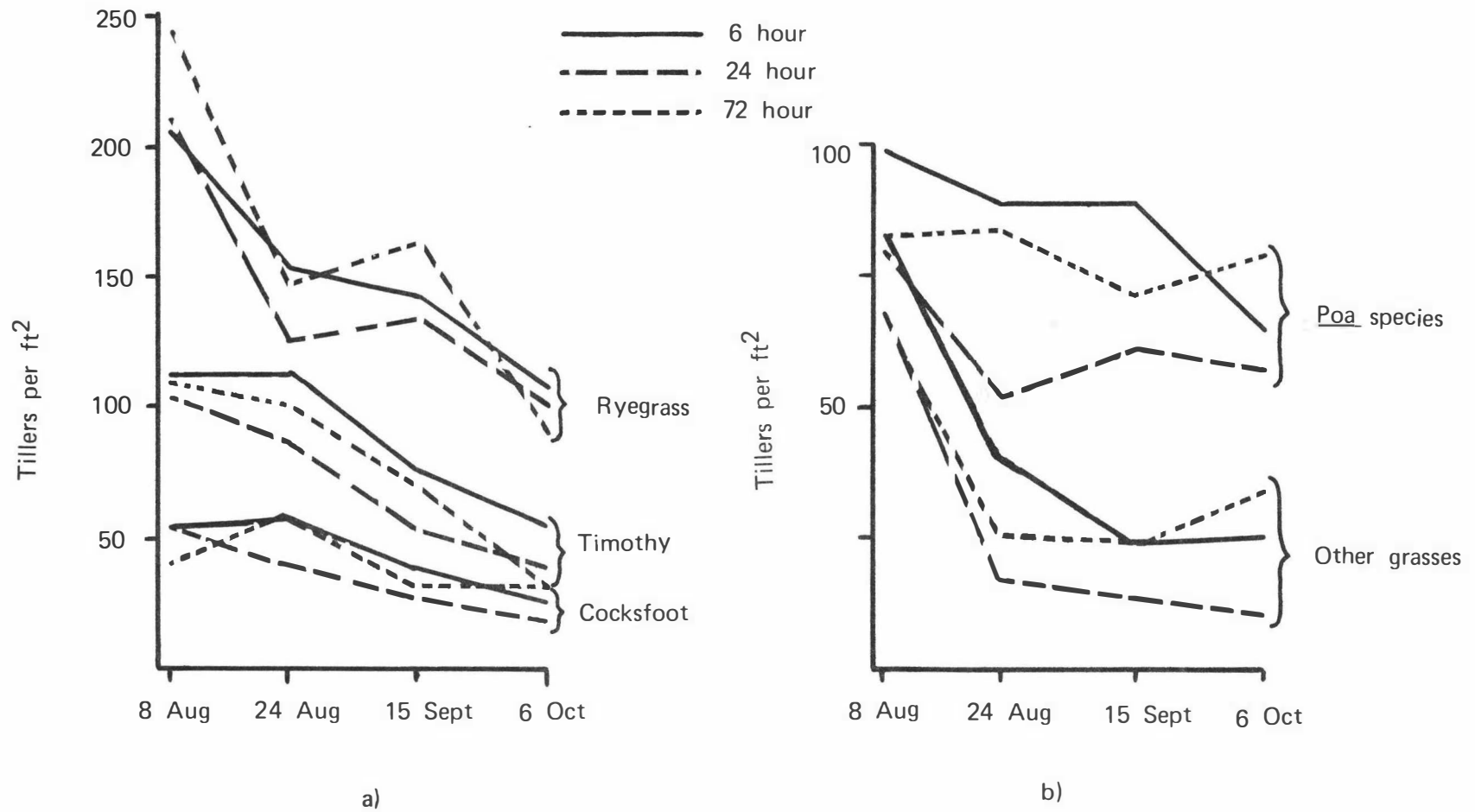
Figure 25 — Experiment II — Grazing duration effect on tiller population

Analysis of variance (Appendix 20) shows a significant $(p < 0.05)$ duration x intensity interaction on 15 September caused by the '6 hour' treatment having significantly more clover nodes per ft^2 than the '24 hour' $(p < 0.01)$ in the 200 cow days per acre treatment but at 120 cow days per acre the '24 hour' was slightly better performed. The interaction however was small compared to the overall superiority of the 72 hour duration at both grazing intensities at this time.

Total Grass Tillers :   The '24 hour' duration had greater effect on grass populations than either the '6 hour' or the '72 hour' durations (Figure 24a);   the differences between durations at each sample data are summarized in Table XXXII.

TABLE XXXII : Experiment II - Grazing duration effects on total grass tiller populations

Comparison	Sample Date			
	8 August	24 August	15 Sept.	6 Oct.
6 - 24	43.2	137.2*	86.7*	66.4*
72 - 24	31.8	105.4[+]	69.7*	37.5
LSD (0.05)	105.2	124.5	93.5	65.6

Tiller densities in the '24 hour' duration treatments are the lowest of all duration treatments in both total sown and unsown grass species and all their respective component species (Figures 24b, 25a and 25b).

<u>Total Sown Grass Species</u> : The decrease due to the
'24 hour' treatment (Figure 24b) almost reached significance at
the 5% level on 24 August and by the 15 September the difference
was significant (p < 0.05) over both other duration treatments.
At the final harvest the differences between duration treatments
were no longer significant.

Trends in total sown grass species are a reflection of
the ryegrass component, though all species show a decrease over
the experimental period and a similar ranking between duration
treatments. Differences due to duration treatments did not
reach significance in the individual component species.

<u>Total Unsown Grass Species</u> : Total unsown grass
(Figure 24b), <u>Poa</u> and 'other grasses' (Figure 25b) tiller
populations all show a similar ranking between duration treatments.
The '6 hour' having more tillers per ft^2 than the '72 hour'
which in turn had more than the '24 hour' treatment. At the
final sample (6 October) the '72 hour' treatment has the
highest population of these components. At no stage do the
differences in the individual components or the total unsown
species component reach significance. To avoid confusion, due
to overlapping values, total unsown tiller populations are not
graphed in Figure 25b.

4.1.7 <u>Soil Moisture</u>

The mean soil moisture measurement at each sample date
over all treatments are given in Figure 12. Analysis of variance
of data at each harvest date showed no significant treatment

effects except for a significant duration effect $(p < 0.1)$ at the last sample date. A t-test on duration means at this harvest showed the '72 hour' treatment to have a significantly higher soil moisture content than the '6 hour' $(p < 0.1)$ and the '24 hour' $(p < 0.05)$ treatments. Inspection of the data found the difference due to one abnormally high value for one plot in the '72 hour' treatment. Data and analysis of variance results are not presented.

4.1.8   Soil Bulk Density

From Table XXXIII it can be seen that at all depths higher bulk densities were achieved under the higher grazing intensity. Analysis of variance (Appendix 21) showed this difference to be significant in the $0 - 3$ cm $(p < 0.05)$, $3 - 6$ cm $(p < 0.1)$ and the overall $0 - 9$ cm $(p < 0.05)$ layers.

TABLE XXXIII : Experiment II - Grazing Intensity and Grazing duration effects upon soil bulk density (gm/cc)

| | | Soil Level (cm) | | | |
		0 - 3	3 - 6	6 - 9	0 - 9
Grazing intensity	120	0.885	1.099	1.087	1.024
(cow days/acre)	200	0.922	1.130	1.107	1.053
SE mean ±		0.011	0.010	0.011	0.008
LSD (0.05)		0.034	0.033	0.034	0.026
Grazing duration	6	0.890	1.109	1.111	1.037
(hours)	24	0.937	1.123	1.094	1.052
	72	0.885	1.112	1.086	1.028
SE mean ±		0.013	0.013	0.013	0.010
LSD (0.05)		0.041	0.040	0.041	0.033

Grazing duration had less affect upon the soil bulk density; only in the 0 - 3 cm layer did analysis of variance show a significant duration effect ($p < 0.05$). A t-test showed this was due to the '24 hour' treatment having significantly greater compaction than both the '6 hour' and '72 hour' treatments ($p < 0.05$).

4.2   Between Days

4.2.1   D.M. Utilization and intake

D.M. intake per cow per day and percentage utilization of available DM are presented in Figures 26a and 26b respectively. In all treatments DM intake per cow is increased in Days 2 and 3 compared to intake in Day 1 (Figure 26a). The average increase in intake in comparison with Day 1 was 13.2% in the 120 cow days per acre intensity and 10.3% in the 200 cow days per acre intensity. Analysis of variance (Appendix 22) fails to show any significant differences between daily intakes within treatments.

Percentage utilization presents a somewhat similar trend to that of daily intake, values are lower in Day 1 than Day 2 and 3 at both grazing intensities. In the 120 cow days per acre treatment utilization is greater in Day 2 than either Day 1 or Day 3 (Figure 26b). Analysis at variance (Appendix 22) however shows no significant differences in percentage utilization between days.

4.2.2   D.M. Production

The mean DM yields over all treatments for each day are presented in Table XXXIV. As shown, regrowth from plots grazed
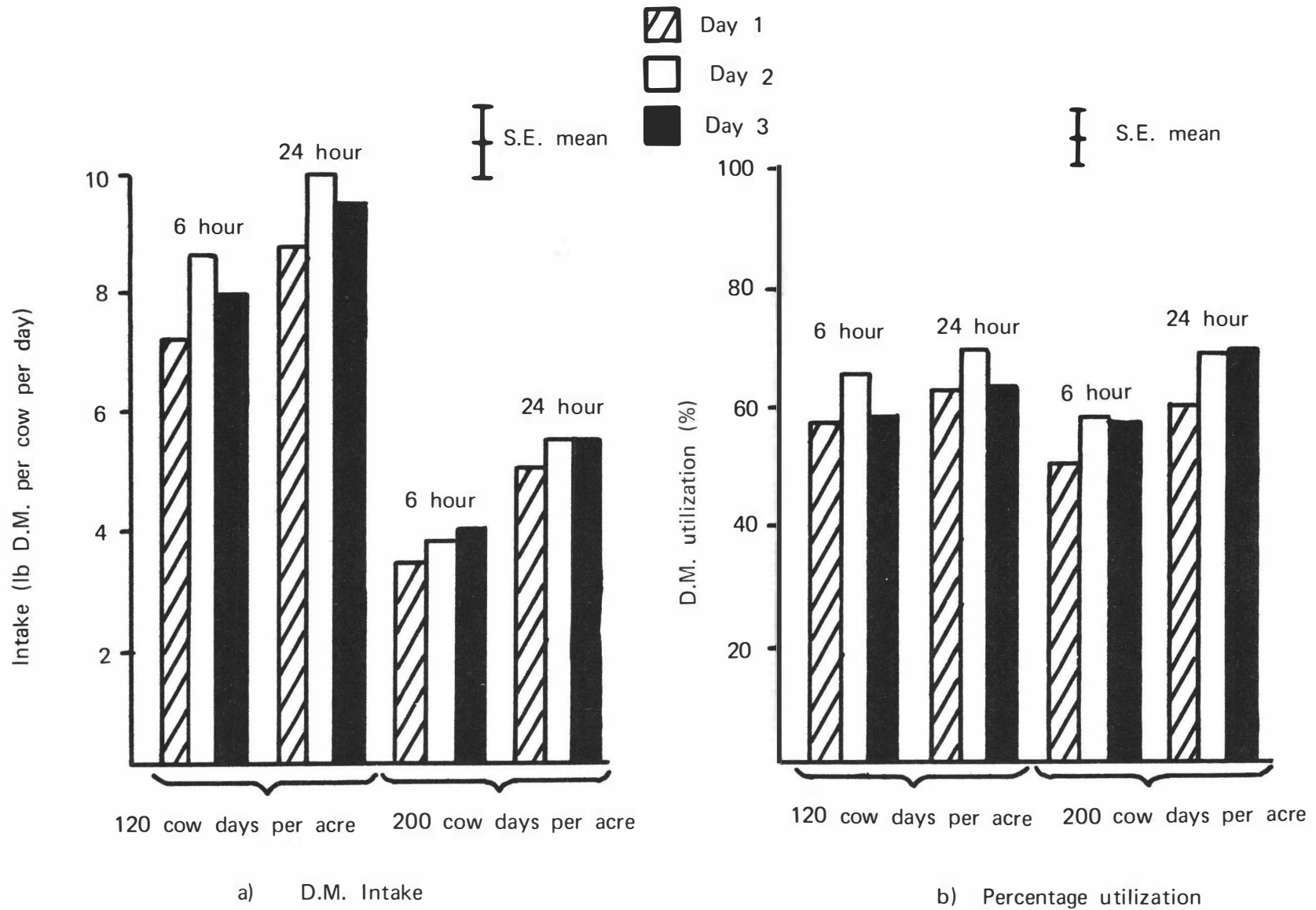
Figure 26 — Experiment II — D.M. utilization and intake between days

on Day 1 was below other plots at all stages, this difference

often reaching significance. The only other significant

between day effect was at 20 days where regrowth from Day 2

plots was shown to be significantly greater than Day 3 plots

($p < 0.001$). Analysis of variance and t-tests (Appendix 23)

also shows significant duration x day ($p < 0.05$) and duration

x intensity x day ($p < 0.01$) interactions at the harvest 20 days

following grazing.

TABLE XXXIV : <u>Experiment II - D.M. production, between days</u>

		Harvest (Days from grazing)					
		0	10	20	30	40	50
Day	1	632	527	810	1262	1868	2562
"	2	519	575	1060	1325	1915	2962
"	3	588	568	903	1361	1944	2888
SE Mean ±		30.5	21.0	16.3	33.9	39.2	64.4
LSD (0.05)		112.0	77.1	60.0	124.5	143.8	236.3

D.M. production for each day at both grazing intensities

for the '6 hour' duration (Figure 27) and '24 hour' duration

treatments (Figure 28) show that grazing intensity has a greater

effect on regrowth than has either grazing duration or environmental

conditions between days. Grazing duration had little effect at

120 cow days per acre but when grazed at 200 cow days per acre

regrowth is restricted when grazing duration is increased from

'6 hours' to '24 hours'. Both intensity and duration effects

are confirmed by data in Table XXVII and Table XXVIII (Section

4.1.3).
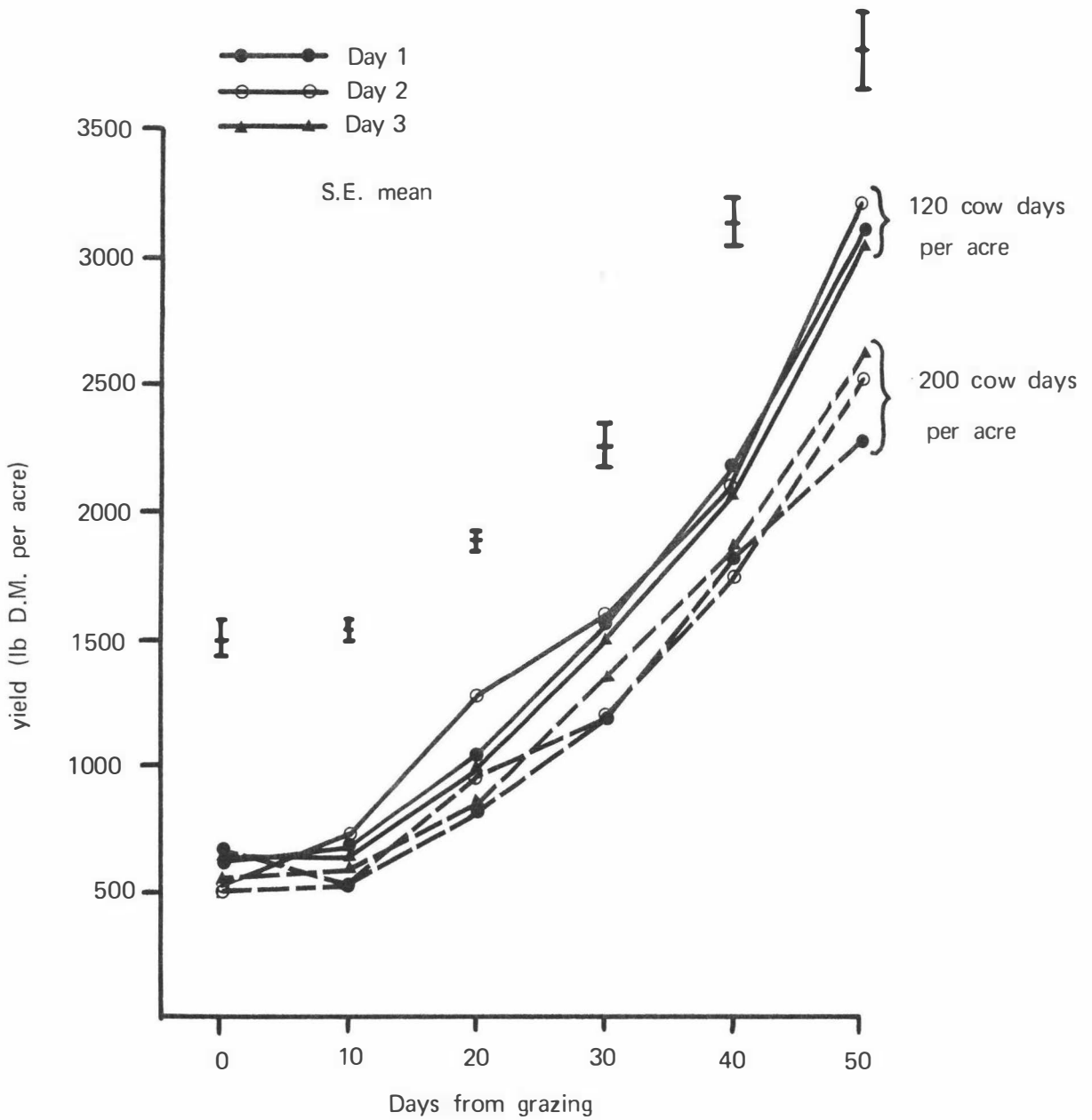
Figure 27 — Experiment II — Grazing intensity effect on between day D.M. production (6 hour durations)
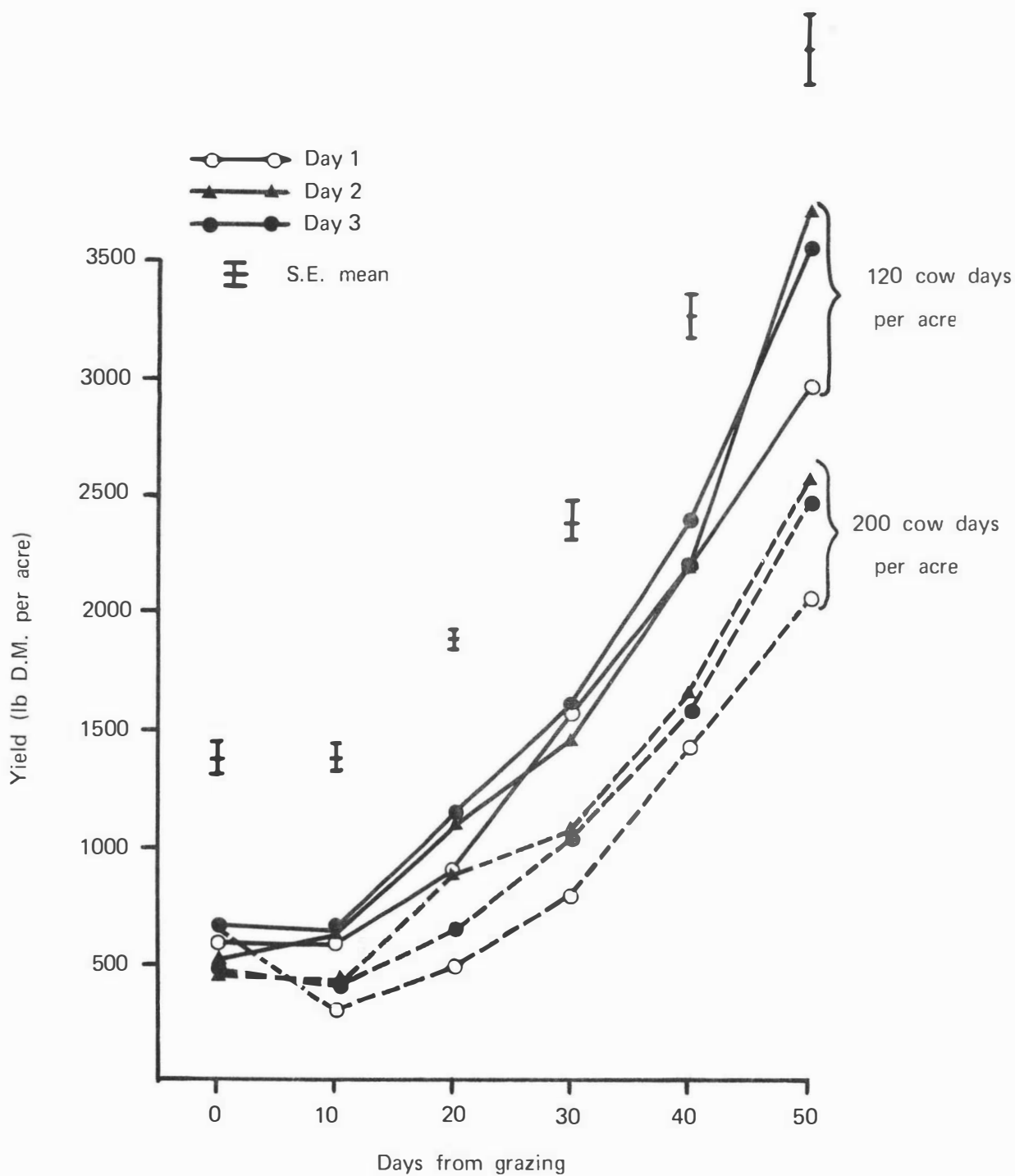
Figure 28 — Experiment II — Grazing intensity effect on between day D.M. production (24 hour duration)

Between days the only difference in Figures 27 and 28 is the inferiority of Day 1 which appears to increase as intensity moves from 120 to 200 cow days per acre and duration from '6 hours' to '24 hours'. The three way interaction at harvest day 20 can be seen in Figures 27 and 28 to be due to regrowth in Day 1 being less than Day 3 in both grazing intensities but significant at the 24 hour duration only ($p < 0.05$ and $p < 0.01$) for 200 and 120 cow days per acre respectively . The duration x day effect is the result of the significant decrease in Day 1 over Day 3 in the '6 hour' treatment at the low intensity adding to the '24 hour' non significant increase, to produce over both durations a non-significant result. This does not occur at 200 cow days per acre.

4.2.3   Relative Growth rates

Table XXXV gives the b values and constants for the regression log DM with time for each of the '24 hour' and '6 hour' durations for each of the three days. Analysis of variance (Appendix 23) shows no significant difference between days within treatments or any day x treatment interactions. The greatest difference between days appears to be in the 200 cow days per acre intensity for the '24 hour' duration (Table XXXV) but differences still fail to reach significance at the 5% level.

Experiment II -

TABLE XXXV : Regression log D.M. with time for between day comparisons

Grazing intensity			'6 hour'			'24 hour'		
		b	SE ± *	Constant	b	SE ± *	Constant
120 cow	Day 1	0.037	0.001	6.17	0.037	0.002	5.95
days/acre	2	0.034	0.003	6.32	0.037	0.003	6.02
	3	0.038	0.001	6.13	0.038	0.001	6.00
200 cow	Day 1	0.041	0.003	5.00	0.048	0.001	5.24
days/acre	2	0.042	0.002	6.04	0.043	0.004	5.69
	3	0.041	0.002	6.11	0.046	0.001	5.51
LSD[+] (0.05)		0.0062					

* SE based on the deviations of mean values about fitted regressions

+ LSD values for comparison of b values.

4.2.4   Botanical Composition

The botanical composition of DM regrowth is represented pictorially in Figures 29 and 30. No noticeable trends are apparent between days within any treatment. Graphing the percentage occurrence of each component of each sample date showed no movement between days of major proportions in any species except ryegrass. Ryegrass and total grass proportions within each treatment are shown in Figure 31 and percentage composition data in Appendix 24.

Following grazing the percentage contribution of ryegrass dropped from pre-grazing levels mainly as a result of dead matter increasing from 6% to 13% over the same period. Differences between days in ryegrass contribution occur immediately after grazing and this is due to an absolute decrease in ryegrass production rather than an increase in any other component. Although overall DM production differences at day 10, between days, were not significant (Table XXXIV) analysis of variance (Appendix 24) shows ryegrass production on Day 1 to be significantly less than Day 2 ($p < 0.05$) but not Day 3. The most noticeable item in Figure 31 is the decrease in the percentage contribution to DM yield of ryegrass in Day 1 as compared to Day 2 and Day 3 at the later stages of regrowth. This effect being present in all treatments. Analysis of variance of total DM production (Section 4.2.2) found production in Day 2 and Day 3 to be significantly greater than that from Day 1 plots at the final regrowth harvest ($p < 0.01$). Analysis of variance of individual components (Appendix 24) only shows between day differences in ryegrass and total sown grass.
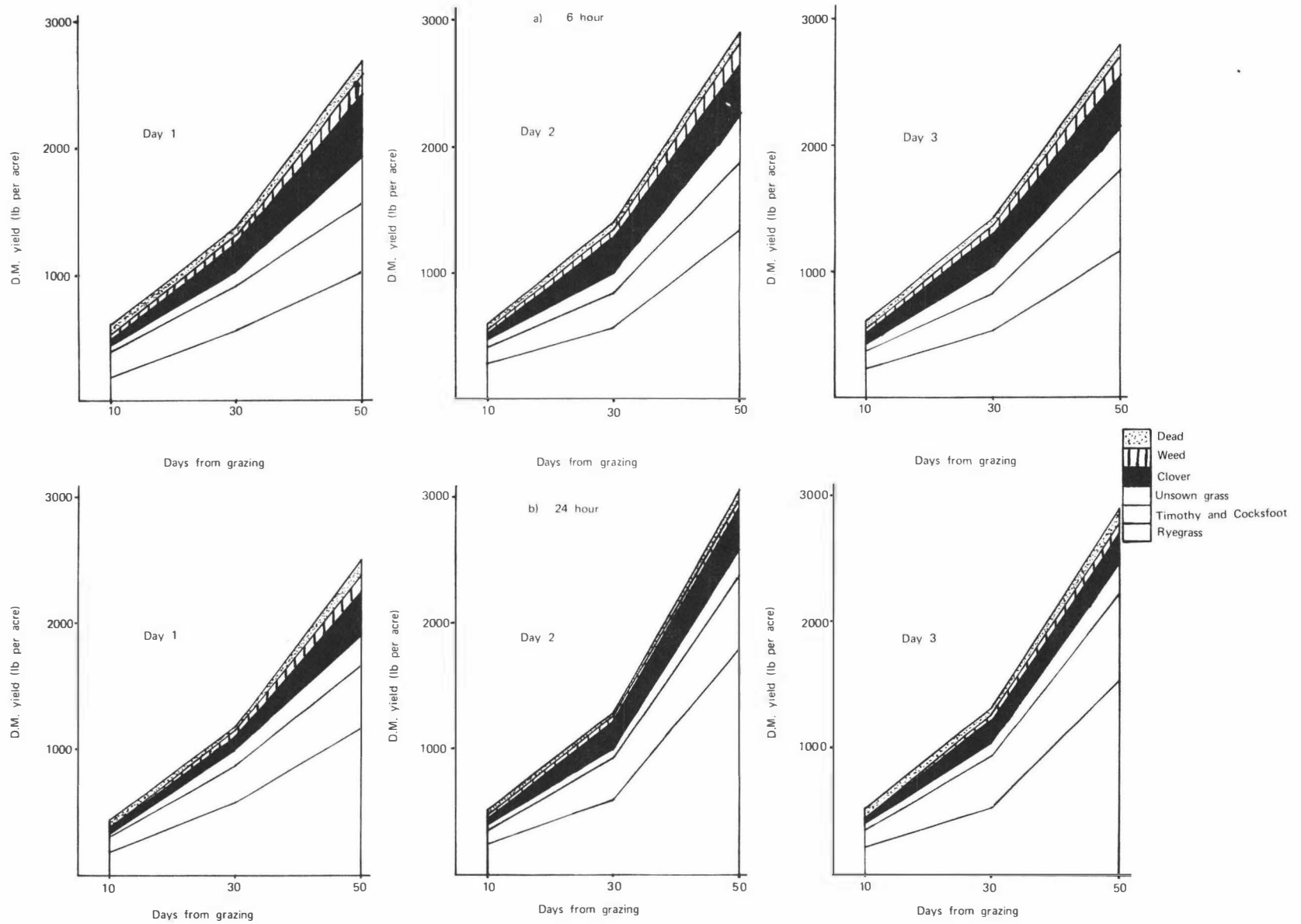
Figure 29 — Experiment II — Grazing duration effect on between day D.M. production (Individual components)

a) 120 cow days per acre

b) 200 cow days per acre

Dead
Weed
Clover
Unsown grass
Timothy and Cocksfoot
Ryegrass
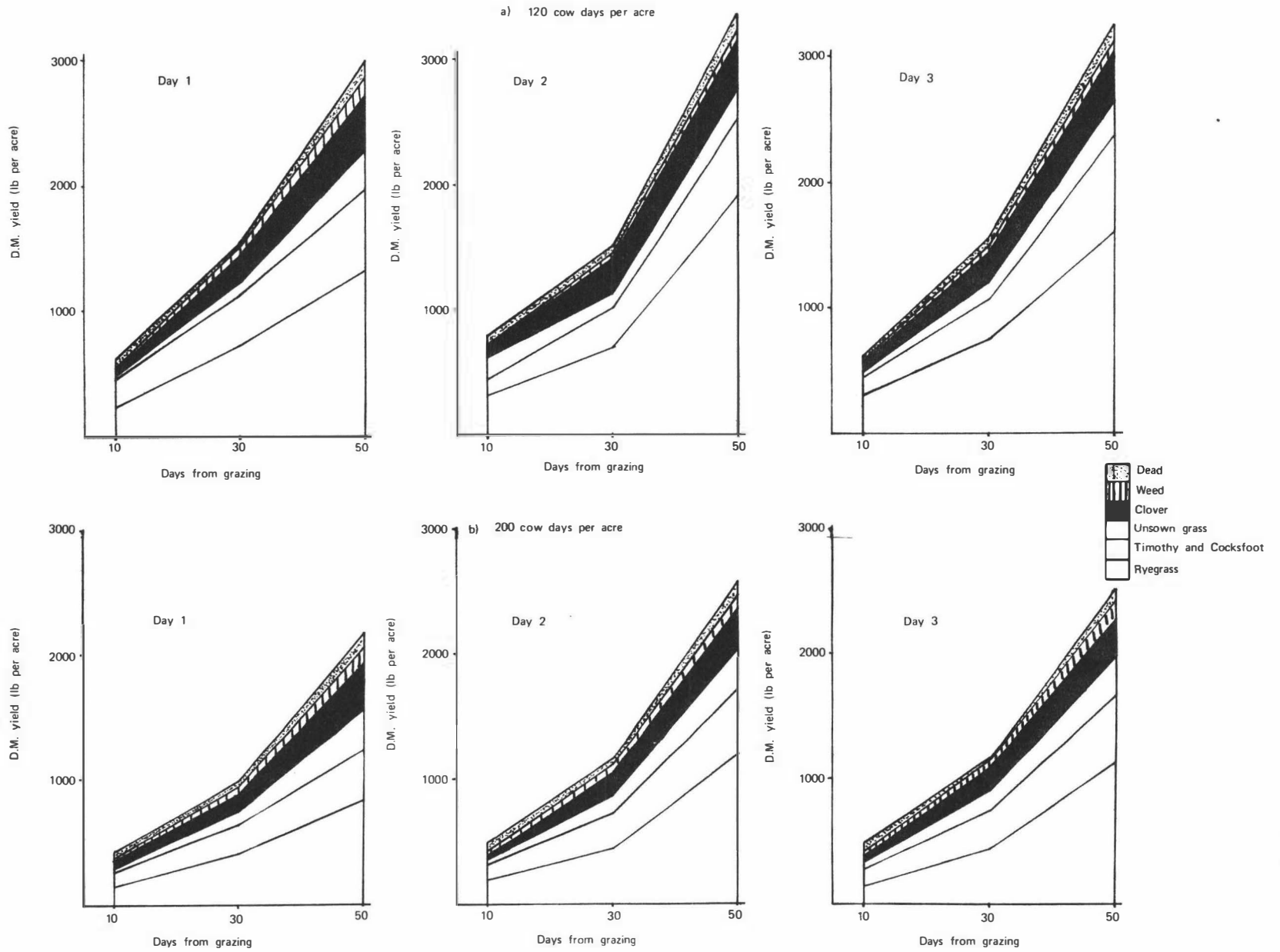
Figure 30 — Experiment II — Grazing intensity effect on between day D.M. production
(Individual components)

152
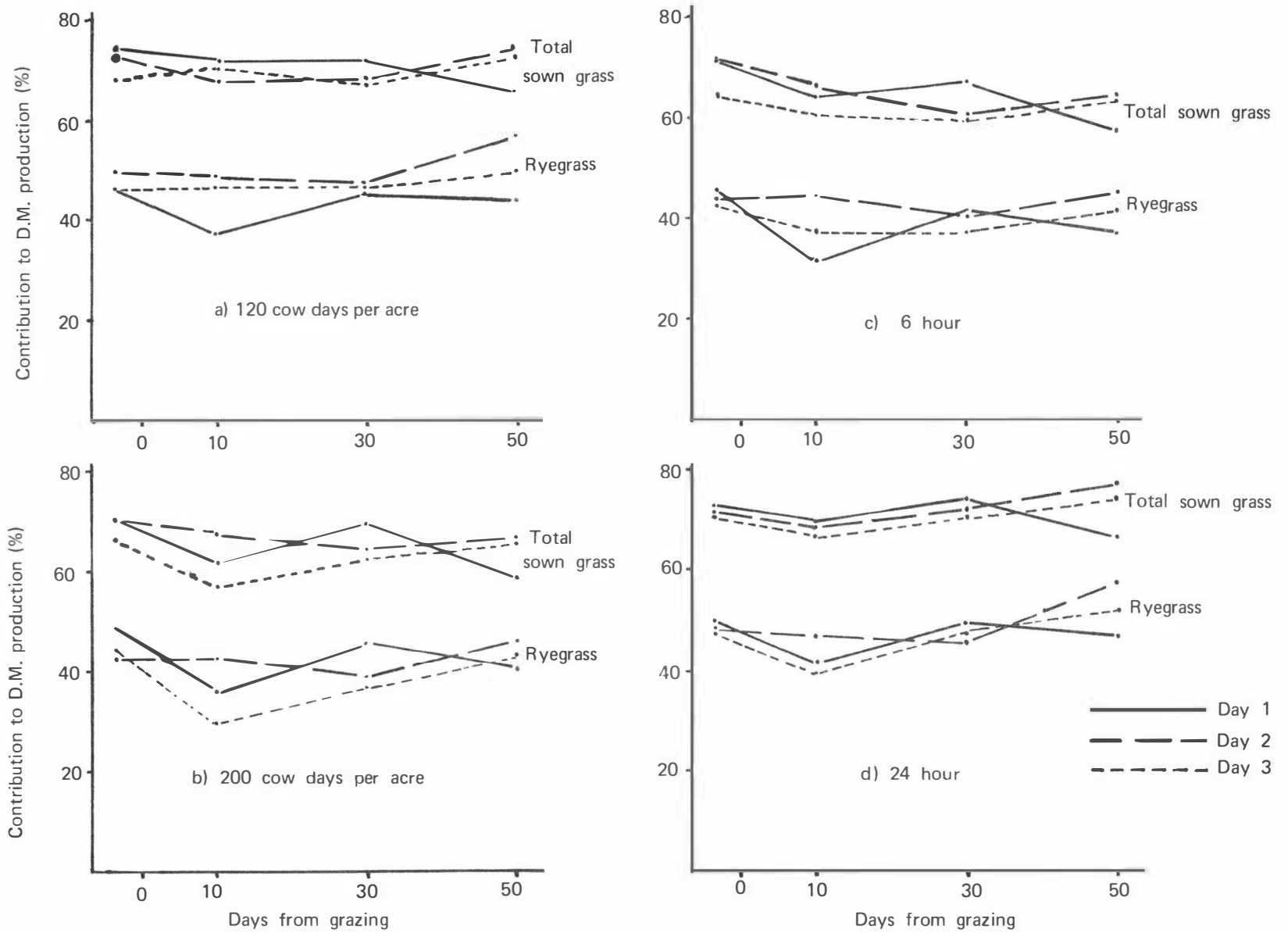
Figure 31 – Experiment II – Between day comparison of botanical composition of D.M. yield (Ryegrass and Total Sown Grass)

Ryegrass production on Day 1 being significantly less than Day 2 $(p < 0.001)$ and Day 3 $(p < 0.01)$ with a similar significance reflected in the total sown species analysis. The difference in DM yield of ryegrass between Day 1 and the average effect of Days 2 and Day 3 at this final harvest is 371 lb DM per acre which is slightly greater than the same comparison in total DM production (363 lb DM per acre). The decrease in ryegrass percentage in Day 1 is due to a decrease in ryegrass production therefore rather than to increases in any other component.

4.2.5   Tiller Density

Only those species showing significant between day or day x treatment interactions will be investigated in this section. The differences between intensities and durations over the mean values have been dealt with in Section 4.6.1. The large quantity of data available in this section makes interpretation of results difficult and to make presentation orderly only the major components clover, total grass, total sown grass and total unsown grass will be covered. Results are presented in Figures 32, 33, 34 and 35 while data, analysis of variance and t – tests appear in Appendix 25. Analysis of variance shows significant day x treatment interactions so consequently results are presented for individual treatments.

Clover

Analysis of variance fails to show any between day differences in clover populations over the regrowth period. This is confirmed when the rooted node densities are graphed for

individual treatments for each of the three days (Figure 32).

Total grass

Figure 33 shows each treatment over the three day experimental period. There were no differences between days prior to grazing though tiller numbers on Day 2 and Day 3 in the 200 cow days per acre - 6 hour treatment were higher than most other treatments. On 24 August results, analysis of variance shows significant day ($p < 0.1$) and day x grazing intensity interaction ($p < 0.1$). The overall mean day difference is caused by Day 1 having significantly fewer tillers than Day 3 plots ($p < 0.05$). Within grazing intensity however differences were only present at the high intensity where Day 1 had significantly fewer tillers than both Day 2 ($p < 0.01$) and Day 3 ($p < 0.05$). This appears real in the '24 hour' treatment (Figure 33d) but the '6 hour' treatment (Figure 33c) is confused by the relatively low value on Day 1 plots prior to grazing.

On 15 September, Day 1 plots at the high grazing intensity, still had significantly fewer tillers per ft^2 than both Day 2 ($p < 0.01$) and Day 3 ($p < 0.1$). A significant day x grazing intensity x grazing duration interaction ($p < 0.1$) can be attributed to two effects; the difference between Day 1 and Day 2 at the high grazing intensity being greater in the '6 hour' than the '24 hour' durations and at the low intensity where Day 3 gives highest tiller density at '6 hours' but the lowest at '24 hours'. As a result of this interaction, in the '6 hour' duration at the lower grazing intensity (Figure 33a), Day 3 has significantly more tillers than both Day 1 ($p < 0.1$) and Day 2 ($p < 0.05$).
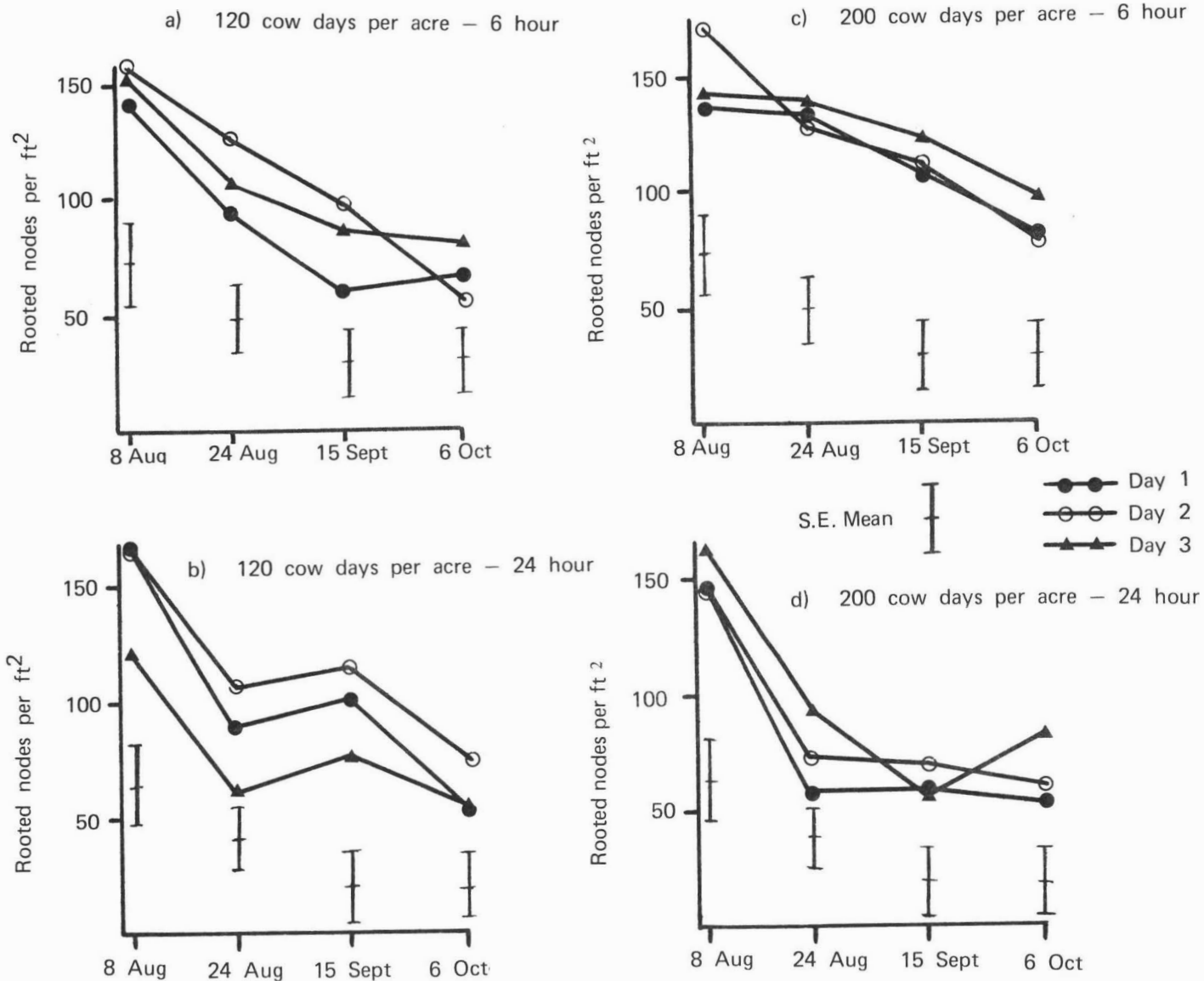
Figure 32 — Experiment II — Between day comparison of clover node populations
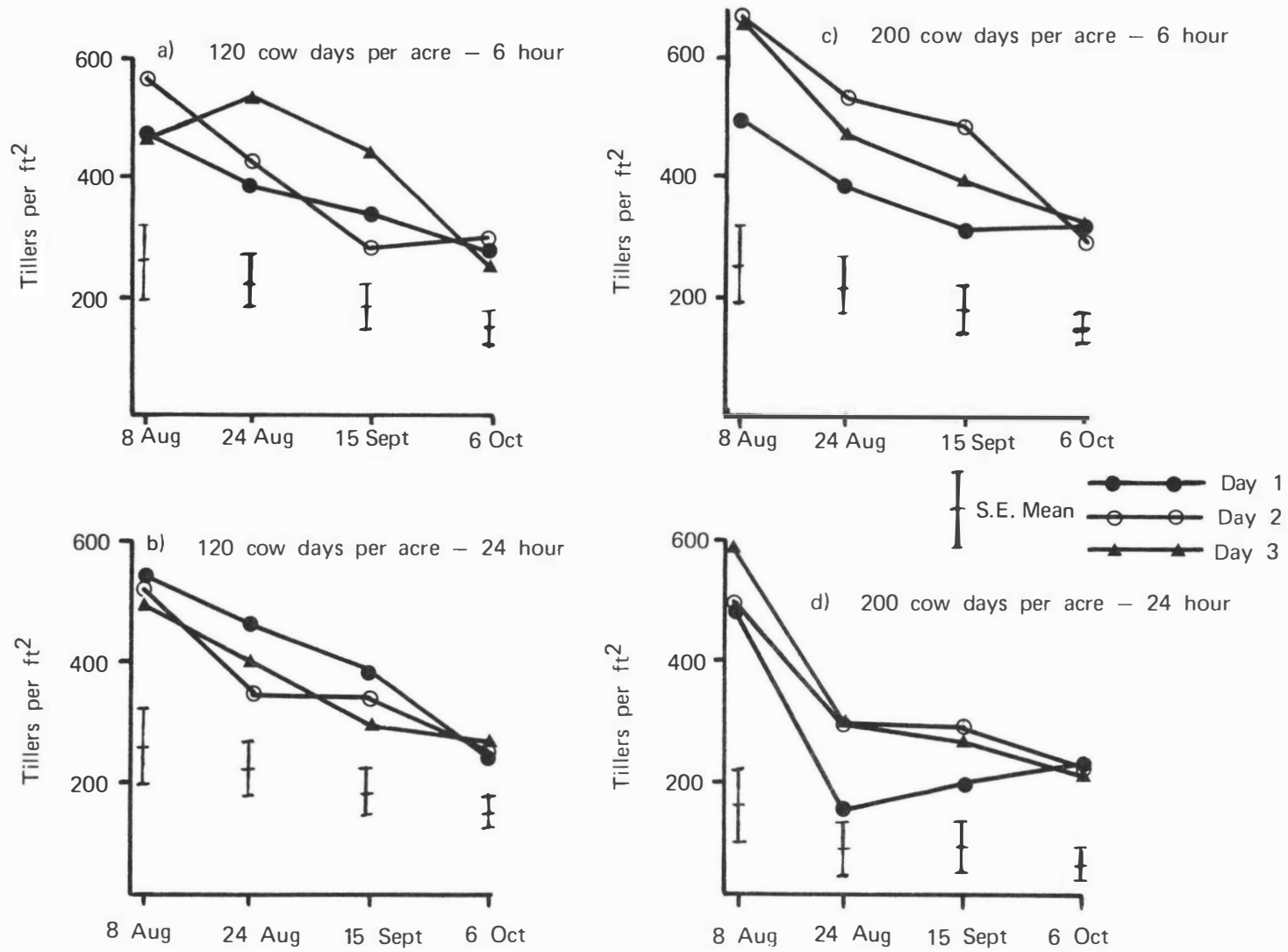
Figure 33 —Experiment II — Between day comparison of total grass tiller populations

a)   120 cow days per acre — 6 hour

c)   200 cow days per acre — 6 hour

b)   120 cow days per acre — 24 hour

d)   200 cow days per acre — 24 hour

S.E. Mean
Day 1
Day 2
Day 3
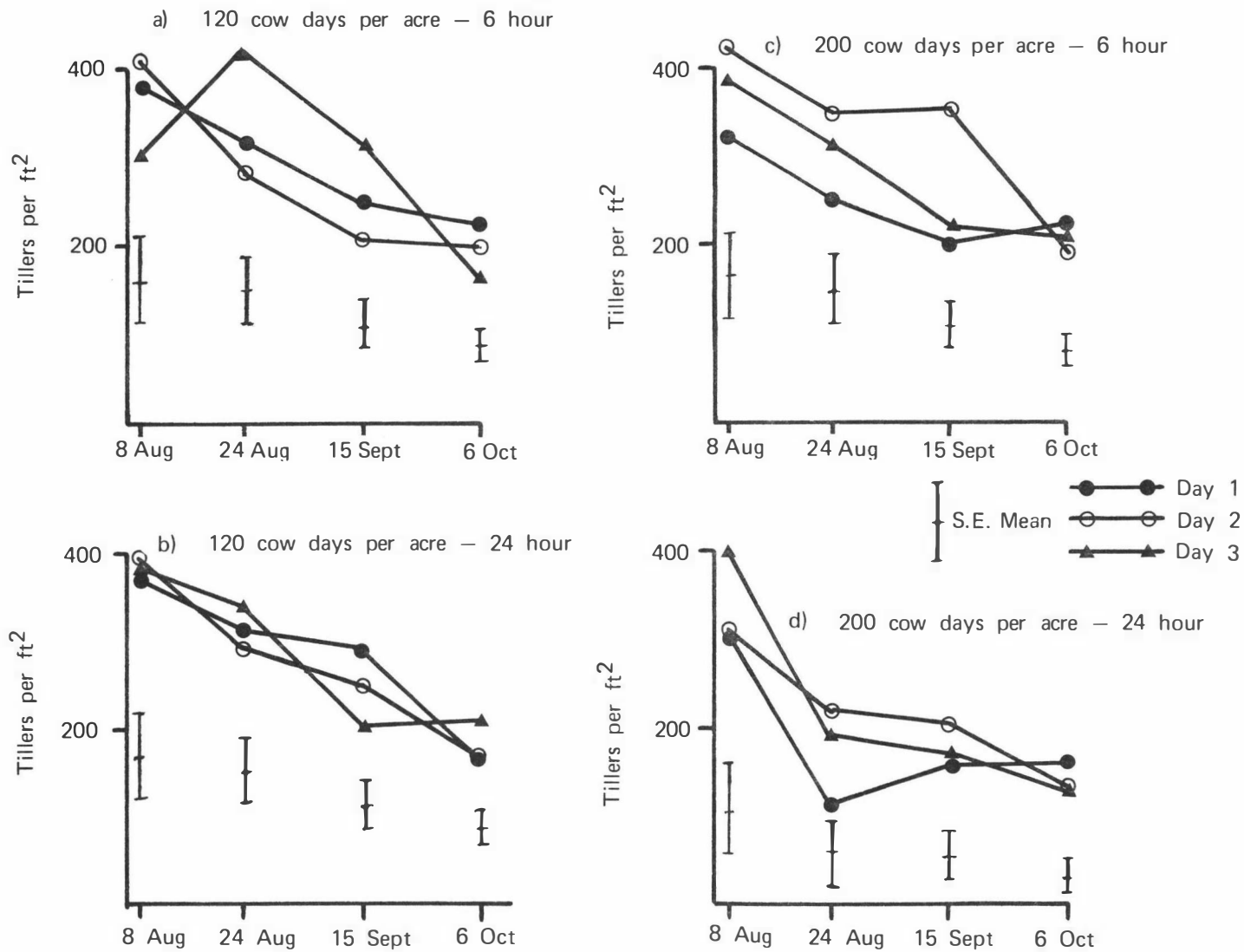
Figure 34 — Experiment II — Between day comparison of total sown grass species
tiller populations
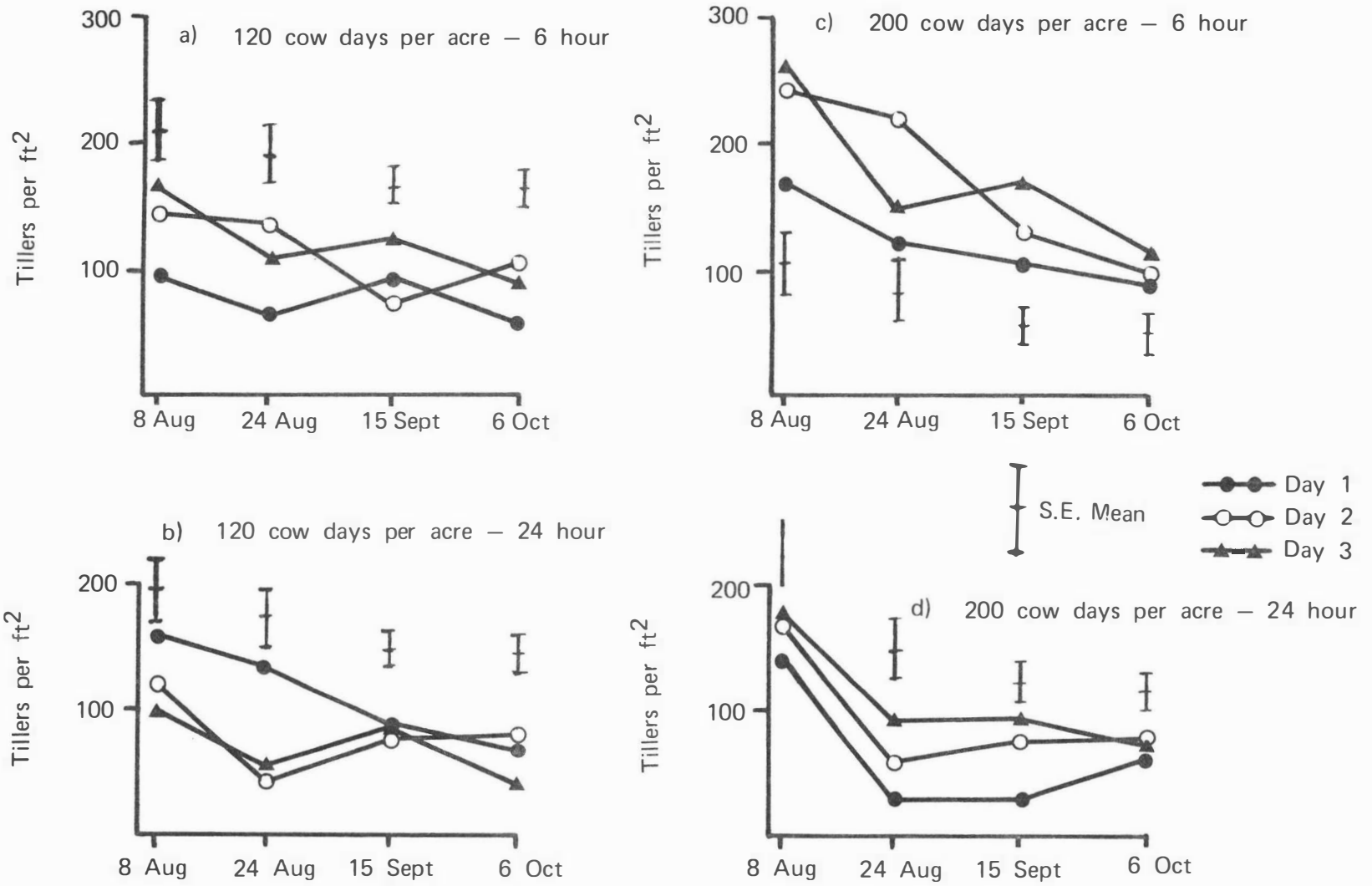
Figure 35 — Experiment II — Between day comparison of total unsown grass species
tiller populations

By the final sample tiller numbers between days within treatments did not differ significantly; as shown in Figure 33 the differences between days on 6 October were smaller than those present before grazing.

Total Sown Species

Between day effects, differed more due to grazing intensity than grazing duration treatments (Figure 34). Few differences between days were found at the low grazing intensity except immodiately after grazing (24 August) when Day 3 had significantly more tillers than Day 2 ($p < 0.05$). At 200 cow days per acre following grazing Day 1 plots had significantly fewer tillers than Day 2 ($p < 0.05$) and Day 3 ($p < 0.1$) and at the next sample (15 September) Day 2 had significantly more tillers than both other days ($p < 0.05$) (Figure 34 c and d).

A significant day x duration x intensity interaction ($p < 0.1$) on 15 September was due to the same factors as caused a similar interaction in the total grass species.

Ryegrass tiller populations follow closely that outlined for total sown grass though the same levels of significance were seldom reached in the component species. Timothy and cocksfoot populations did not always react in a similar manner to the ryegrass population but the differences involved in tillers per ft^2 between days within these minor components were small in comparison to the total tiller populations present.

Total Unsown grass species

The high initial value for Day 2 and Day 3 total grass tiller populations in the 200 cow days per acre – 6 hour

duration treatment (Figure 33c) are due to the unsown grass

tillers in the sward (Figure 35c). A significant day x duration

interaction $(p < 0.1)$ before grazing is due to Day 2 and Day 3

having significantly more tillers per ft^2 in the '6 hour '

duration $(p < 0.05)$ but not the '24 hour' duration.

Analysis of variance of results over the regrowth period

shows greater differences between days due to duration than to

grazing intensity. These show that in the '6 hour' treatments

Day 1 was below the remaining days at most sampling dates. Table

XXXVI shows the difference between Day 1 and Days 2 and 3 in the

mean '6 hour' grazing duration treatment. The differences existing

prior to grazing is in most cases larger than that after grazing

making it impossible to say whether any real effects took place

in the unsown species due to grazing duration.

TABLE XXXVI : <u>Between day differences in unsown grass tiller</u>
<u>populations due to a '6 hour' grazing duration</u>

Comparison	8 Aug.	24 Aug.	15 Sept.	6 Oct.
Day 3 — Day 1	84*	34	46**	31+
Day 2 — Day 1	64*	95**	2	30+
LSD (0.05)	61.6	52.5	32.1	35.3

A three-way interaction $(p < 0.1)$ on 24 August is caused

mainly by at the '24 hour' duration Day 1 having most tillers:

but at the high intensity it had the least. As a result of

this interaction t-tests show Day 1 to have significantly more

tillers per ft^2 than both Day 2 and Day 3 $(p < 0.05)$ at the

low intensity (Figure 35b) while at the high intensity the extremes failed to reach significance at the 5% level.

Total unsown species reactions are a direct reflection of the Poa component as the 'other grass' component showed no difference in tiller populations between days within grazing treatments.

4.2.6   Soil Moisture

Analysis of variance of data at each sample date indicated no significant results due to treatments during the experimental period and therefore neither the data nor analysis of variance results are presented. Mean soil moisture values for all plots have been previously presented in Figure 12b.

4.2.7   Soil Bulk Density

Analysis of variance (Appendix 26) between days within the '6 hour' and '24 hour' duration treatments showed a significant between days difference ($p < 0.1$) only at the deepest level tested (i.e. 6 - 9 cm depth). t-test results (Appendix 26) indicated the significance was the result of the soil bulk density being significantly greater in plots grazed on Day 1 than on Day 2 ($p < 0.05$).

The grazing duration x day interaction approached significance in the 0 - 3 cm level, reached significance ($p < 0.01$) in the 3 - 6 cm level and was non-significant in the 6 - 9 cm level. This trend was reflected by a significant duration x day interaction ($p < 0.05$) on the overall 0 - 9 cm level. Results are therefore

presented in Table XXXVII showing soil bulk densities for each day within the '6 hour' and '24 hour' grazing durations;   each value being the mean of two grazing intensities.

Observation of Table XXXVII shows '24 hour' treatments at all levels tested to fall in bulk density from Day 1 to Day 3 while in the '6 hour' treatment the movement is less marked and more variable but at all levels highest soil bulk densities were obtained on Day 3. This trend gives rise to the significant duration x day interaction in the 3 – 6 cm and 0 – 9 cm levels.

TABLE XXXVII   :   Experiment II – Between day, grazing duration effects on soil bulk density (gm/cc)

		Day	Soil level (cm)			
			0 – 3	3 – 6	6 – 9	0 – 9
	6	1	0.888	1.094	1.116	1.033
		2	0.890	1.104	1.095	1.030
Grazing		3	0.891	1.130	1.122	1.048
duration		1	0.968	1.145	1.113	1.075
(hours)	24	2	0.936	1.124	1.080	1.047
		3	0.911	1.101	1.090	1.034
SE Mean ±			0.015	0.015	0.011	0.009
LSD (0.05)				0.045		0.019

0 – 9 cm level :

t-test results show the small differences between days at the '6 hour' duration are largely non-significant but Day 3 has a significantly greater soil bulk density than Day 2 $(p < 0.1)$.

In the '24 hour' duration however grazing in Day 1 has resulted in a higher soil bulk density than in Day 2 ($p<0.01$) and Day 3 ($p<0.001$). Within days the removal of animals after 6 hours grazing gave a significant reduction in soil bulk density in Day 1 ($p < 0.001$) a smaller reduction in Day 2 ($p<0.1$) and a non-significant increase in Day 3.

3 - 6 cm level :

The only difference between days to reach significance is in the '24 hour' duration where Day 1 has a greater soil bulk density than Day 3 ($p< 0.1$). Within days the two duration treatments only had significantly different effects on soil bulk density in Day 1 ($p <0.05$).

4.3   Control (cut) v's grazed

4.3.1   D.M. utilization and intake

Results of estimated intake and percent utilization on control and grazed plots at both defoliation intensities are presented in Table XXXVIII. Data and analysis of variance results appear in Appendix 27.

TABLE XXXVIII : Experiment II - Defoliation treatment effect on D.M. utilization and intake

Treatment		Intake (lb D.M./cow day)	Percent Utilization
120 cow days	grazed	8.54	63.7
per acre	cut	7.96	55.0
200 cow days	grazed	4.67	60.8
per acre	cut	6.13	71.5
SE Mean ±		0.65	2.6
LSD (0.05)		2.25	8.9

Analysis of variance shows a highly significant increase in intake with a decrease in intensity $(p < 0.01)$. Within defoliation treatments however (Table XXXVIII), the grazed treatments gave significantly higher intakes $(p < 0.01)$ at the lower intensity but this difference between defoliation intensity failed to each significance between cutting treatments. Within defoliation intensity, differences in estimated intake per cow per day with cutting or grazing treatments did not reach significance.

Analysis of variance shows a significant defoliation intensity effect $(p < 0.05)$ and a highly significant interaction effect $(p < 0.01)$ in percentage utilization. The intensity effect is due to the cut treatment only, where utilization was significantly greater at the highest intensity $(p < 0.01)$. Within defoliation intensity, cutting gave a lower percentage utilization than grazing $(p < 0.1)$ at 120 cow days per acre but gave a higher percentage utilization than grazing $(p < 0.05)$ at 200 cow days per acre; the differences were 8.7 and 10.7 percentage units respectively.

4.3.2   D.M. production

Results are presented in Figure 36 for defoliation treatments at each of the two grazing intensities. Table XXXIX presents the treatment means, differences and LSD values. Data and analysis of variance appear in Appendix 18-1 and 18-2 respectively.

The analysis of variance results show highly significant defoliation treatment effects throughout the regrowth period. Interaction between defoliation intensity and defoliation method is large and significant at the first three post-grazing harvests (Table XL).

TABLE XXXIX : <u>Experiment II - The effect of cutting and grazing on D.M.</u>
<u>production (lb D.M./acre)</u>

Defoliation treatment	Harvest (Days from defoliation)						
	Pre-	Post-	10	20	30	40	50
Cut	1697	607	965	1237	1705	2226	3186
Grazed	1559	579	536	906	1340	1937	2796
Cut-grazed	138	28	429	331	365	289	390
LSD (0.05)	140.0	65.9	49.5	77.4	103.4	201.7	259.0
(0.001)	270.2	127.1	95.5	149.3	199.6	389.2	499.9

TABLE XL : <u>Experiment II - D.M. production, significant results due to defoliation</u>
<u>treatment</u>

	Harvest (Days from defoliation)						
	Pre-	Post-	10	20	30	40	50
Defoliation Intensity	n.s.	*	***	***	***	***	***
Defoliation method	+	n.s.	***	***	***	**	**
Interaction	n.s.	**	**	+	n.s.	n.s.	n.s.
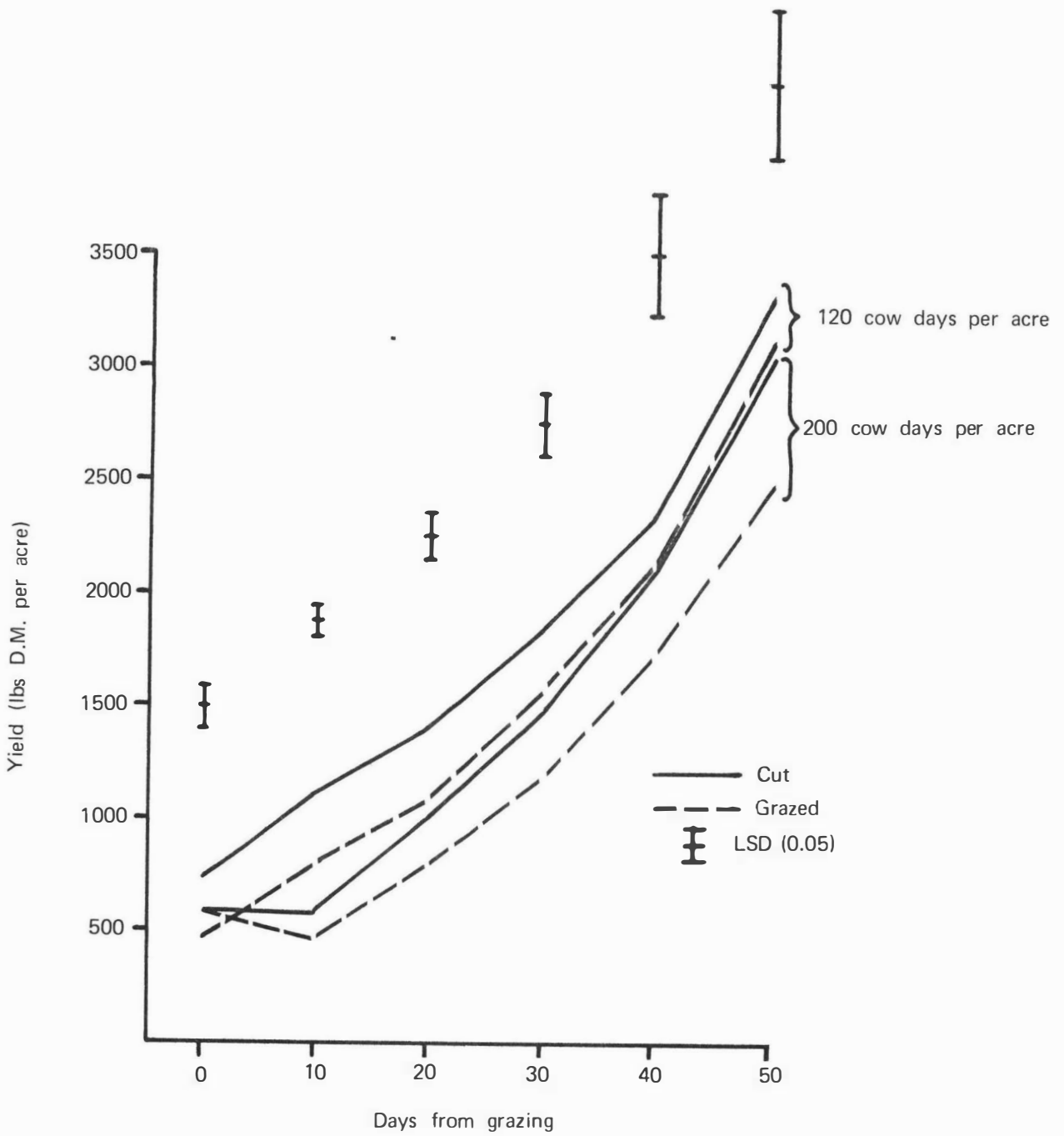
Figure 36 — Experiment II — The effect of defoliation treatment on D.M. production

Defoliation intensity x defoliation treatment interactions appear in Figure 36. t-test results show the significant analysis of variance result in the post grazing harvest for grazing intensities to be due to differences between grazing intensities only ($p < 0.001$). At the low intensity, cutting had 166 lb DM per acre more than grazed plots and at the high intensity 110 lb DM per acre less; the differences reaching significance at the 1% and 5% levels respectively. Interactions at days 10 and 20 are due to the differences between grazing intensities being greater in the cut than the grazed plots. In both intensities cut plots had significantly higher DM yields than grazed plots, the difference in all cases was significant at the 0.1% level.

4.3.3   Relative growth rates

Regressions of log DM with time from day 10 to day 50 for cut and grazed plots at the two defoliation intensities are presented in Table XLI.

TABLE XLI : Regression log DM with time for defoliation treatments

Defoliation intensity	cut			grazed*		LSD[+] (0.001) (0.05)
	Coeff.	SE±	Constant	Coeff.	Constant	
120 cow days/ acre	0.027	0.001	6.72	0.041	6.04	0.0078
200 cow days/ acre	0.033	0.001	6.35	0.041	5.78	(0.004)
LSD[+](0.001)(0.05)				0.0096 (0.005)		

+ LSD values for comparison of regression coefficients.

* SE not available.

Analysis of variance (Appendix 18-4) shows a highly significant defoliation treatment effect ($p < 0.001$) and a significant intensity and defoliation interaction term ($p < 0.1$). t-tests show in both grazing intensities the relative growth rates of the cut plots is significantly lower than that of the grazed plots ($p < 0.001$), and that a significant difference in growth rates between grazing intensities occurs in the cut plots ($p < 0.05$) but not the grazed plots.

4.3.4   Botanical Composition

Plots cut in preference to grazed (Figure 37) appear to receive a smaller contribution from ryegrass species but an increased contribution from unsown species. DM production for cut and grazed treatment means, expressed as a percentage (Appendix 28) show two noticeable effects (Figure 38).

i.   The decrease in ryegrass percentage following grazing in both defoliation treatments caused by an increased contribution from dead matter in the grazed treatments and a relative increase in all other grass components in cut treatments.

ii.   A decrease in ryegrass and an increase in unsown grass components in cut plots relative to grazed plots as regrowth proceeded. The increase in unsown grass was due mainly to an increase in Yorkshire fog as Poa species held similar proportions between defoliation treatments.

Within defoliation intensity the only difference appeared to be in the unsown component. Cut plots at the 120 cow days per
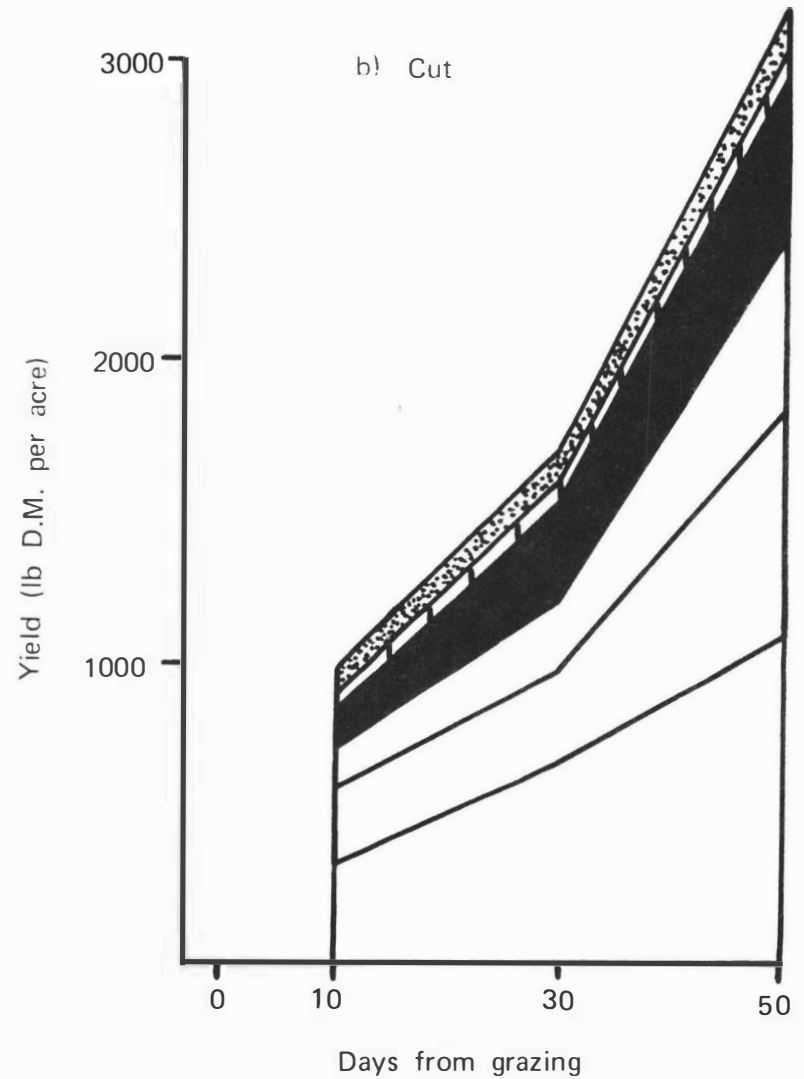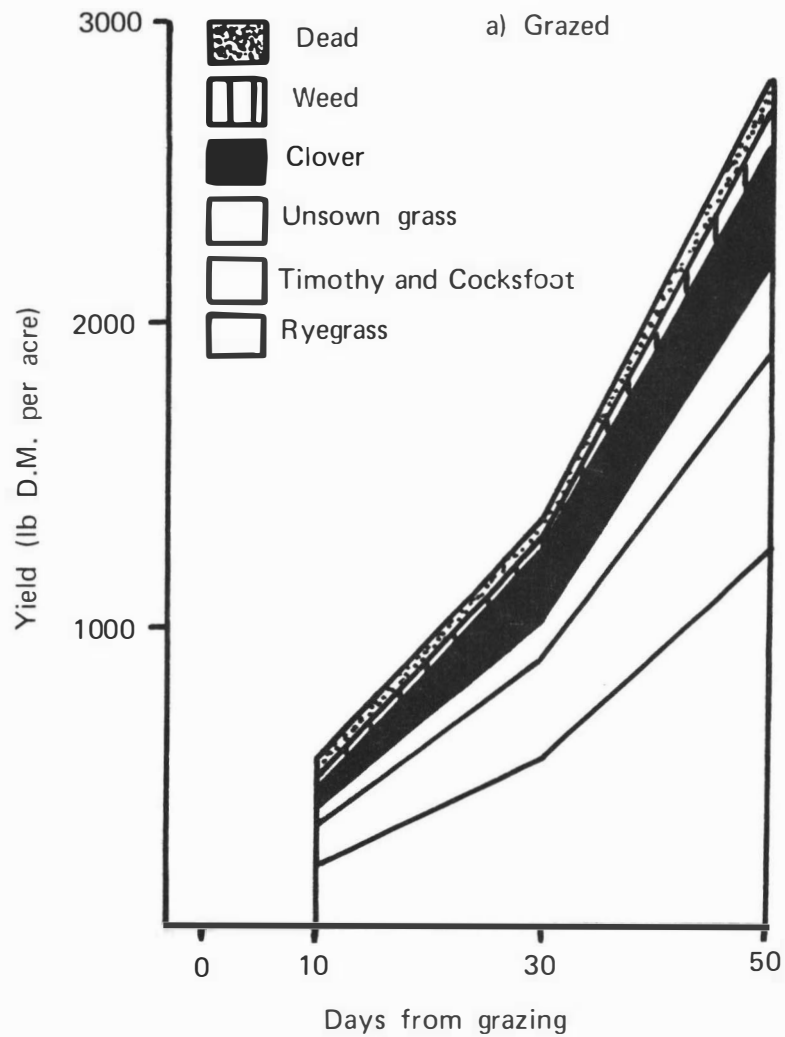
Figure 37 — Experiment II — The effect of defoliation treatment on the D.M. yield of botanical components
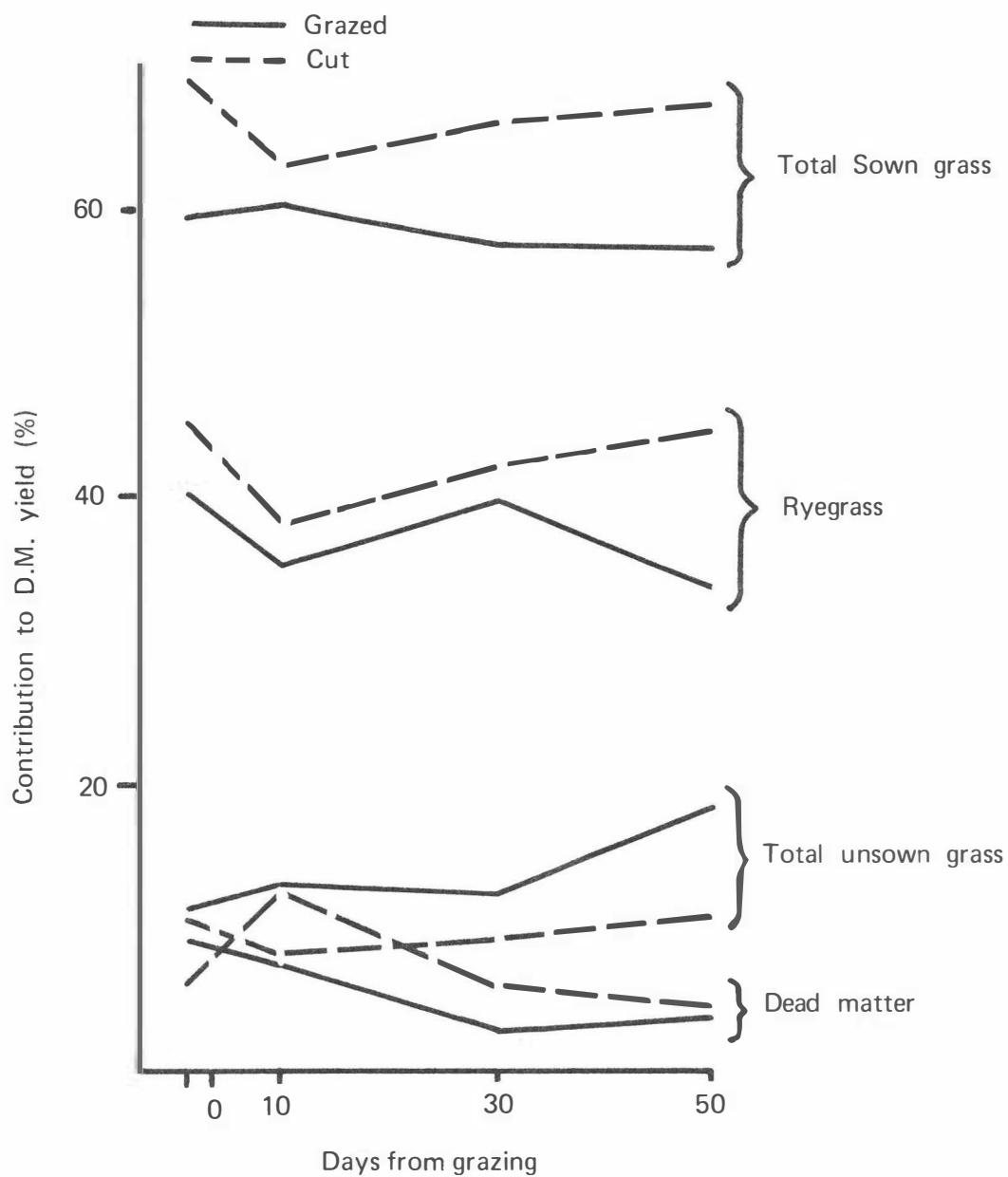
Figure 38 — Experiment II — Defoliation treatment effects on percentage contribution to D.M. yield of botanical components

acre treatment had on average 87% more unsown grass species

than grazed plots. At 200 cow days per acre intensity the

corresponding figure was 51%.

4.3.5   Tiller Density

Results of defoliation treatments on tiller populations

over the two defoliation intensities are presented in Figures 39

and 40. Data, analysis of variance and t-test results appear in

Appendix 29.

Clover nodes

After defoliation the depression of 73 clover nodes/ft^2

when plots were grazed rather than cut (Figure 39a) was highly

significant $(p < 0.01)$. During regrowth the difference between

treatments was somewhat smaller with the difference of 29 nodes

per ft^2 at the final sample (6 October) still being highly significant

$(p < 0.01)$.

Total Grass

Cut plots had 60% more grass tillers than grazed plots

ten days after defoliation (Figure 39a). The difference being

highly significant $(p < 0.01)$. Cut plots had higher tiller numbers

throughout the regrowth period, the increase over grazed plots was

still highly significant $(p < 0.01)$ on 15 September but by 6 October

the difference of 54 tillers per ft^2 just failed to reach significance

at the 5% level $(LSD_{(0.05)} = 55)$. Both sown and unsown grass species

show a similar trend (Figure 39b), though the difference between cut

and grazed treatments is more marked in unsown species.

Total Sown Grass Species

A highly significant increase $(p < 0.01)$ of 126 tillers
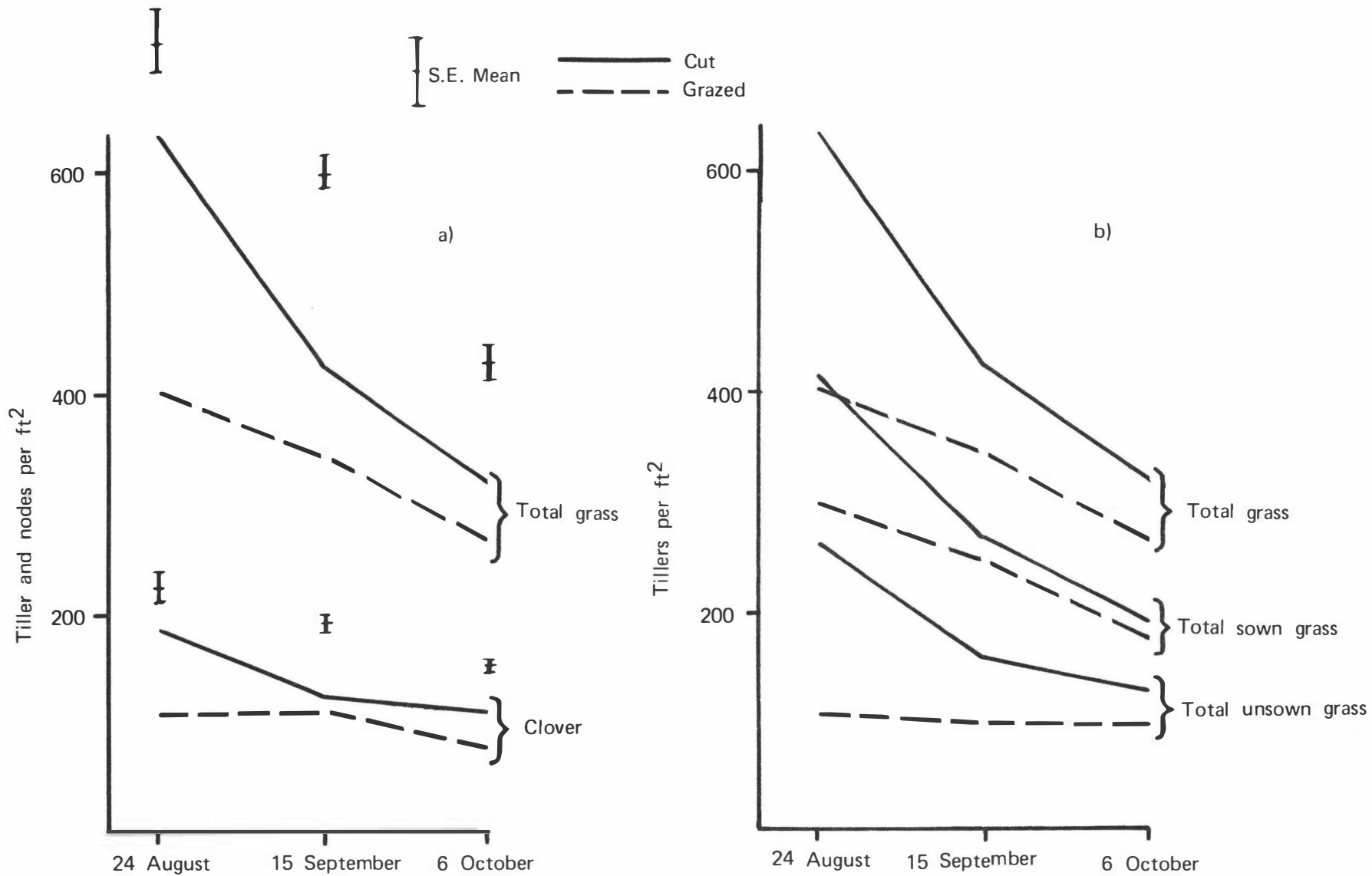
Figure 39 — Experiment II — The effect of defoliation treatment on tiller populations
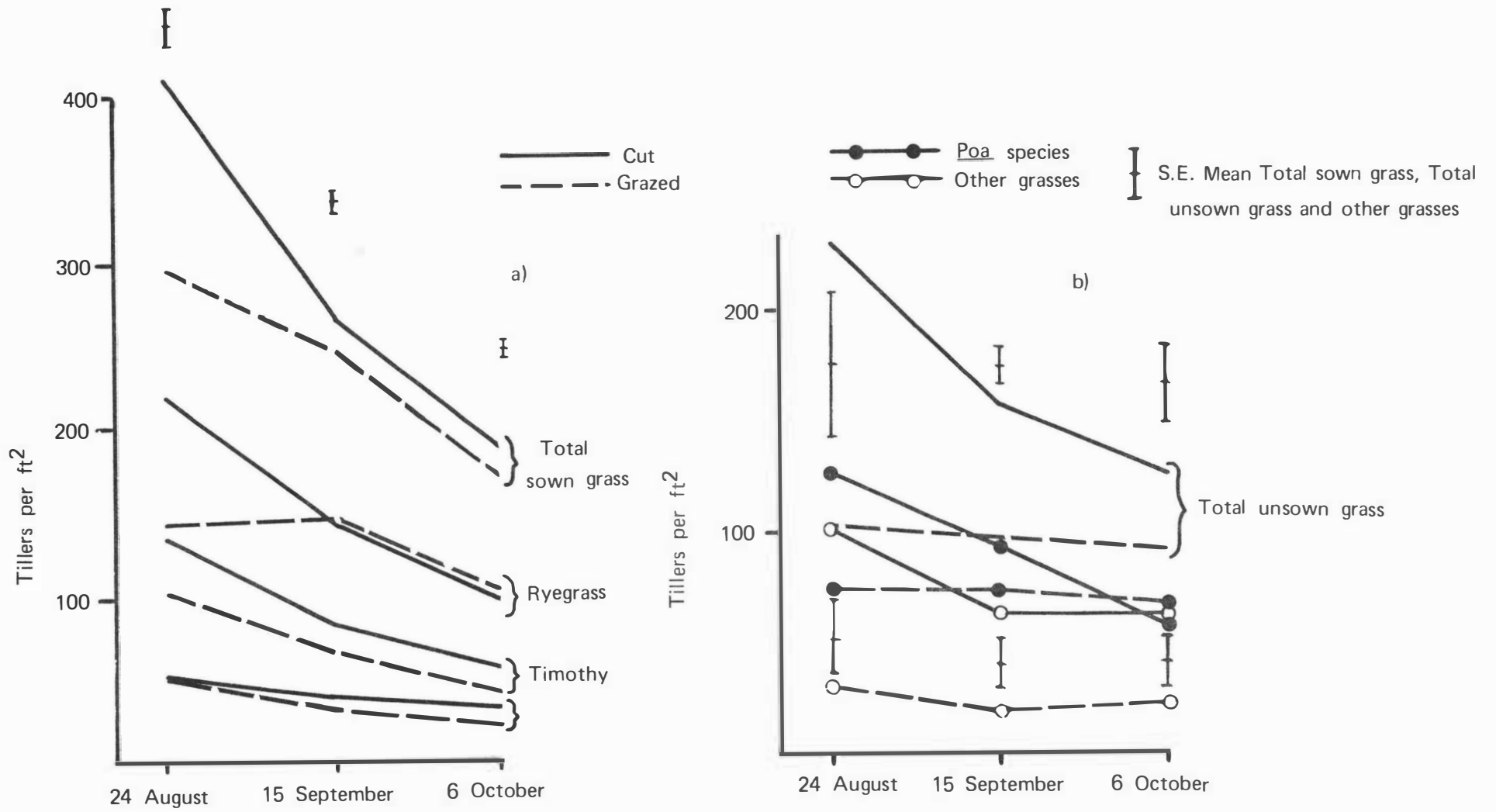
Figure 40 — Experiment II — Defoliation treatment effects on tiller populations

per ft^2 was recorded ten days after defoliation when plots were cut rather than grazed. At the remaining samples this difference was reduced to 20 tillers per ft^2 (non-significant). The timothy and ryegrass components reflect the trend shown in total sown species while cocksfoot appears less sensitive to defoliation treatment (Figure 40a).

Total Unsown Grass Species

Cutting gave significantly more unsown grass tillers per ft^2 than grazing (Figure 39b) on 24 August ($p < 0.05$) and 15 September ($p < 0.01$). The difference had lost significance by 6 October. Figure 40b shows the other grass component to contribute, to the difference, to a greater extent than do Poa species. At no stage did the difference between defoliation treatments reach significance in Poa species but in other grasses significance was reached at all sample dates (24 August and 15 September, $p < 0.05$; 6 October, $p < 0.1$).

Species behaved in a similar manner between defoliation treatments within defoliation intensity except for the total grass, total sown grass and ryegrass components. Their response to grazing intensity are graphed in Figure 41. At the lower intensity tiller numbers in cut plots of all three fall markedly between 24 August and 15 September, in comparison to the higher defoliation treatment. On 15 September, the difference (cut-grazed) is significant for total grass ($p < 0.01$) and total sown species ($p < 0.05$) at 120 but not 200 cow days per acre. These differences are reflected in intensity x defoliation treatment interactions in analysis of variance on 15 September for total grass ($p < 0.1$)
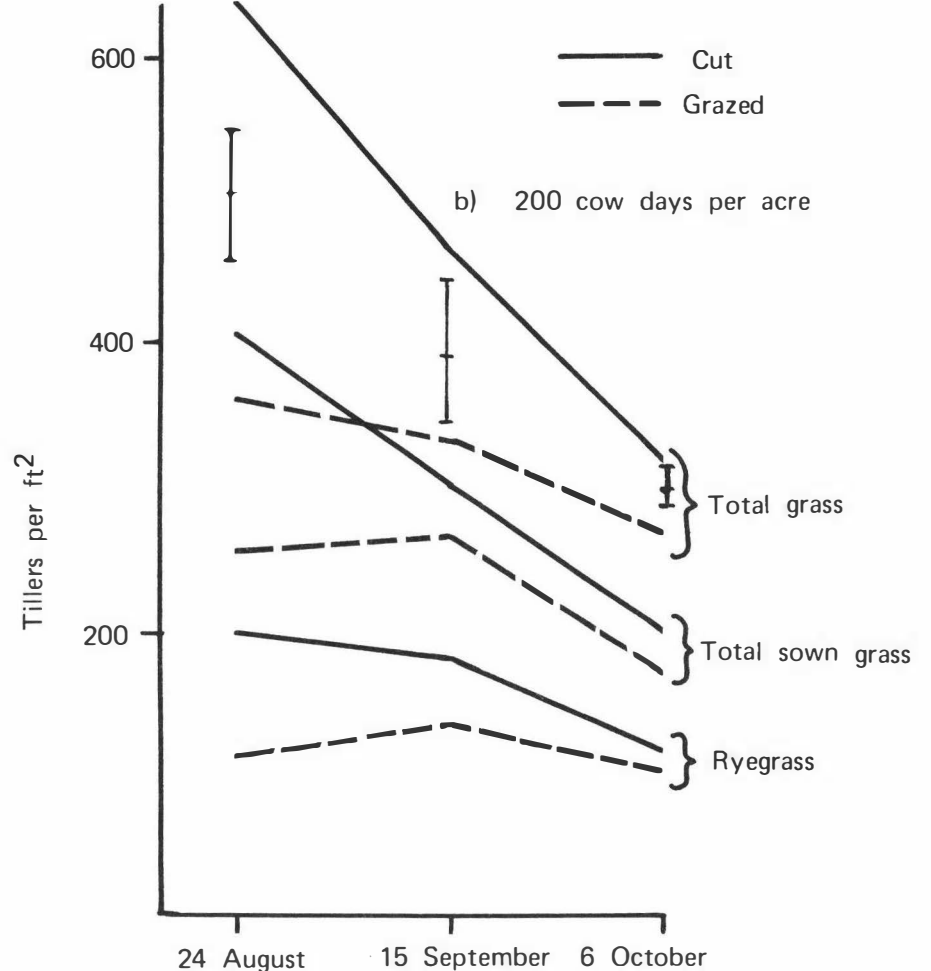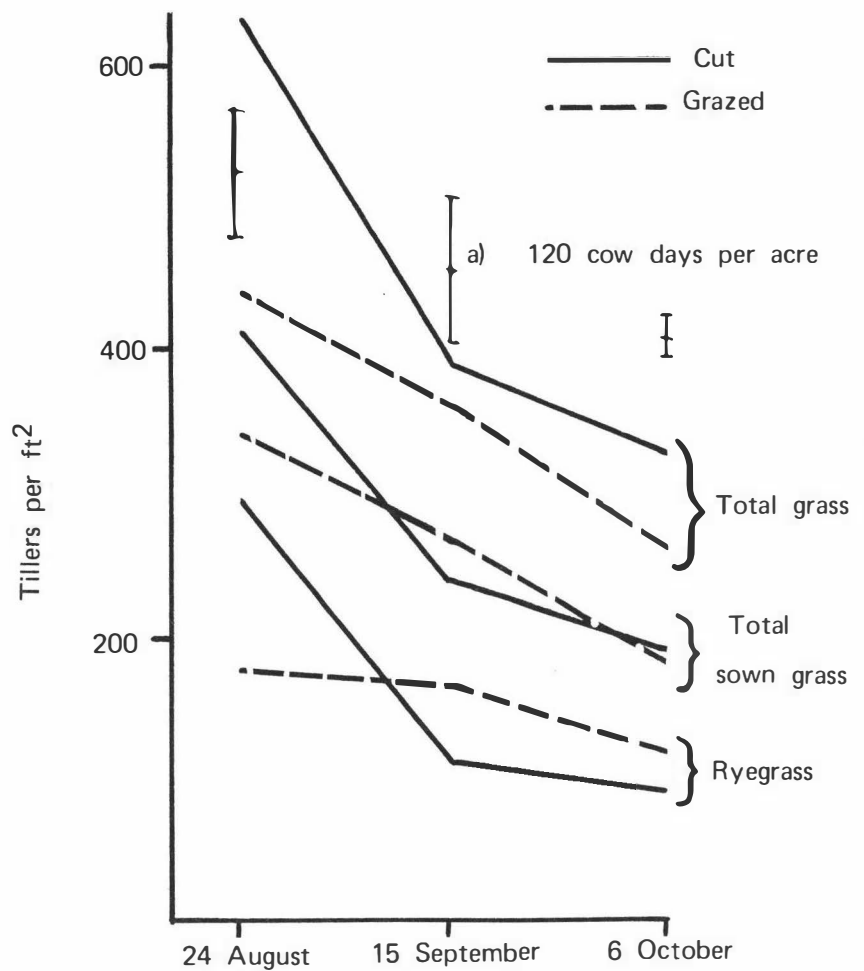
Figure 41 — Experiment II — The effect of defoliation treatment, within defoliation intensity, on tiller populations

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and total sown grass species $(p < 0.05)$.

4.3.6 Soil Moisture

The grazed plots had slightly lower soil moisture values than the cut plots (Table XLII) but this difference failed to reach significance at any sampling date. Data and analysis of variance results appear in Appendix 30.

TABLE XLII : Experiment II – Defoliation treatment effect on soil moisture (%)

Defoliation Treatment	25 August	8 September	22 September	6 October
Grazed	37.6	34.4	34.6	23.5
Cut	38.3	35.8	35.2	24.3
SE Mean ±	0.55	0.95	0.89	0.58
LSD (0.05)	1.91	3.29	3.07	1.94

4.3.7 Soil Bulk Density

Results are presented in Table XLIII with data and analysis of variance in Appendix 31. Although the bulk densities in the control groups are consistently lower than those in the grazed plots it is only in the 0 – 3 cm layer that this difference is significant $(p < 0.05)$.

TABLE XLIII : <u>Experiment II − Defoliation treatment effect on</u>
<u>soil bulk density (gm/cc).</u>

| | Depth | | | |
	0 − 3 cm	3 − 6 cm	6 − 9 cm	0 − 9 cm
Grazed	0.904	1.114	1.097	1.021
Control	0.834	1.075	1.065	0.992
LSD (0.05)	0.031	0.082	0.074	0.090
SE mean ±	0.0052	0.0134	0.0121	0.0148

CHAPTER V

DISCUSSION

5.1   Experimental Design and method

Before discussing the results presented in Chapters III
and IV it is necessary to cover the design of the trial and measurement
methods used in the execution of the two experiments.

The grazing intensities studied (120 and 200 cow days
per acre) are equatable to those in general farm practice. Figure
42 outlines the wintering systems that would involve such grazing
intensities. The actual length of the wintering period refers to
that period over which block grazing is practised. Many farmers
prefer not to use block grazing until as late as mid-June and
before this time using dry animals to graze out areas of the farm
before closing for ASP and winter saved pasture (WSP). Under the
dry conditions in May and early June the dry herd is grazed on
a whole paddock basis. Such farmers would have a short wintering
period (60 days) while others implementing block grazing at an
earlier date or those having later than normal calving dates have
longer wintering periods (90 days). For the use of a similar
proportion of the farm for wintering, a 50% increase in the length
of the winter period is equivalent to a 50% increase in stocking
rate (Figure 42). Since the trial was designed grazing intensities
above those used in the trial have become more commonplace. No. 2
Dairy, Ruakura, employs levels of around 300 cow days per acre for
the winter period (Campbell pers.comm.). Although grazing
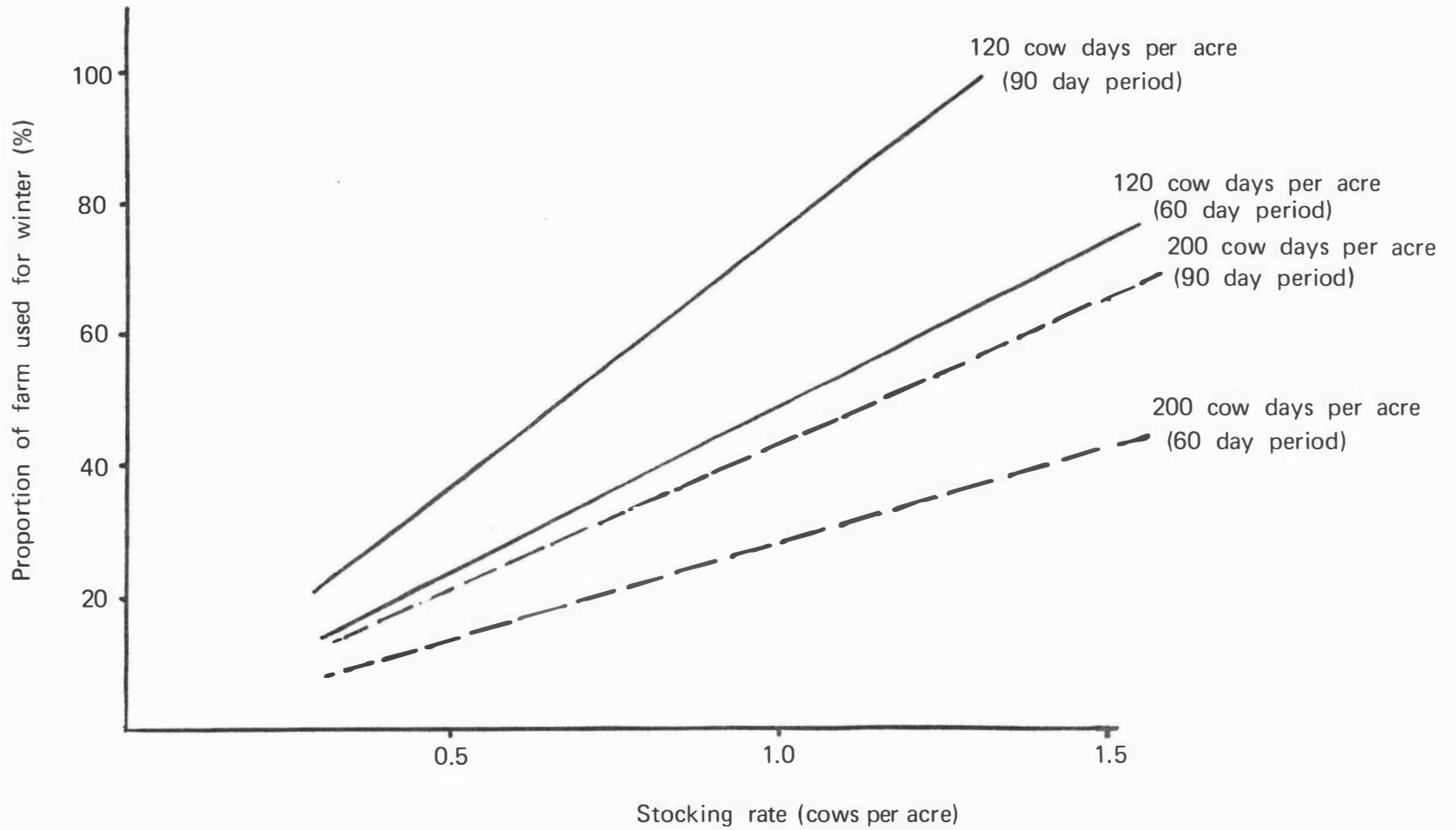
Figure 42 — Wintering systems associated with grazing intensities of 120 and 200 cow days per acre

intensities in excess of 400 cow days per acre have been observed these higher values are the exception rather than the rule. The values chosen of 120 and 200 cow days per acre are by no means unrealistic.

In the practical situation, it is normal procedure to operate a '24 hour' grazing duration when block grazing at high intensities. The '6 hour' treatment was incorporated to study the wintering on pasture but with the minimum of animal damage to the pasture. On the evidence of Wallace (1958) who obtained intakes of 9 lb and 10.9 lb D.O.M. for average grazing durations of 2.8 and 4.3 hours respectively, the grazing duration chosen could have been shorter. Animals in this trial were required to defoliate to much lower stubble heights and probably were subjected to higher grazing pressures than those discussed by Wallace. It was decided therefore to use a grazing period of 6 hours but to incorporate the provision of removing cows after 4 hours if rain was encountered over the grazing period. Only on the first day of grazing in Experiment II were the cows removed after 4 hours. The 24 hour duration in common use is based on convenience and observation rather than on any factual pasture data. It is generally observed that cows appear to damage pasture less and graze more evenly when under this management system than is the case with longer grazing durations. It was also thought desirable to incorporate a treatment involving a less intensive management than the '24 hour' system and see whether this reduction in management resulted in marked changes in pasture response. The '72 hour' treatment was included with this in mind.

Salmon and Hanson (1964) observed that"....in actual
practice there appears to be no unanimity of opinion as to how
many animals should be included in any experiment". They cited
literature talking in terms of 3 to 5 animals per plot. A similar
figure is also given by Lucas and Mott (1962) of from 2 to 5 animals
per pasture. As a result 3 animals per plot was considered the
least practicable number in this experiment – as the number
available and area of land was limited. Any increase in the number
of animals per plot would have meant a decrease in replication and/
or the numbers of treatments studied; neither of which appealed.
It can be argued that a group of 3 cows will not act in a similar
manner to a herd of 100 cows under the same management. With
the high intensities used the confinement of animals irrespective
of number is intense and as 54 cows were used for each trial,
covering a mere $1\frac{1}{4}$ acres, the groups of 3 were far from isolated.
It was thought however that the treatments imposed gave a reasonable
simulation of the conditions ocurring with larger groups of animals.

The plot size ranged from 0.015 to 0.075 acre (Table VIII).
All cows used were from experimental herds and did not appear
upset by the size of plot or by movement in or around plots. Cows
were drawn from a number of sources and hence were previously
under varying winter feeding regimes. Pre-treatment before the
actual trial was therefore thought desirable and extended over a
period of 3 days. This probably conditioned the cows in the '6 and
24 hour' durations more successfully that those at the '72 hour'
duration as the last were subjected to only one grazing cycle and
the others to three. However, the cows appeared to settle down
rapidly to the grazing method adopted, which would support the

observation of Hancock (1954) that cattle will adjust to a grazing system within 24 hours.

The allocation of cows to treatment, as described in Section 2.4, appeared more successful in Experiment II (Section 4.1.1) than in Experiment I (Section 3.1.1.). In Experiment I the cattle at the high intensity were 35 lb lighter than those at the low intensity. This could perhaps have been due to the wider weight range (500 lb to 1012 lb) recorded in cows in Experiment I or possibly to chance. The method used was quick and easy to operate. With large numbers of 2 year old heifers and mature cows this method of allocation was thought more realistic than a strictly random approach.

Layout of plots, construction of fences, gateways and races, and the powering of fences proved successful and ran smoothly. Fences were regularly tested with a voltmeter to ensure at least 1000 volts was supplied to all wires. Two-wire fences could possibly have been adequate but the third wire practically eliminated creep grazing and any chance of cows breaking out of plots.

Pasture Measurements

In a grazing situation three aspects can be measured :

i. The productivity of the pasture

ii. Intake of the animal or the utilization of the pasture.

iii. The nutritive value of the pasture; how a given feed intake is reflected in terms of animal products.

It is the first and second items which were studied with possibly the first being of major concern. As the main interest

was agronomic all measuremen.ts were made on the pasture even though these cutting techniques do not give a very good estimate of the value of the pastures to the animal. This is due to the selectivity (Arnold 1960) and variability between animals in their choice of diet (Arnold 1964) and to the variation existing between animals in their ability to convert pasture to utilizable products (Blaxter 1962). Under high intensities, as practised in these experiments, with restricted selectivity, short grazing periods and low cutting heights, the cut samples are reasonable estimates of quantity if not quality of herbage available before and residues after grazing. It is in this situation that most critics observe pre- and post-grazing D.M. figures to be of their greatest value as an estimate of D.M. intake and utilization. When comparing such estimates with others derived from animal methods (e.g. chromogen-chromic oxide or other indicator techniques) the comparison is obscured by the problem of their being no absolute measure of intake in the grazing situation. Both methods involve substantial errors (e.g. Line, 1959; Carter, 1962; Langlands, 1967; 1969; Moule, 1964).

In studies involving excessive treading damage by animals, sampling immediately following grazing has seldom been attempted. Both Edmond (pers.comm.) and Campbell (pers.comm.) acknowledge the difficulty involved in obtaining such a sample. But without a post-grazing sample there is no estimate of the utilization at the time of grazing. Consequently, it was thought desirable to obtain such a sample as it was felt that in wet conditions losses in D.M. at grazing could possibly be more important than those appearing in later regrowth. The method used (Section 2.4.2.) appeared satisfactory in the recovery of plant residue. As the

grazing period was short (at the most three days) decomposition
of pasture damaged directly as a result of grazing was considered
to be negligible. The major problem was the time taken in washing
and dissecting samples and in the determination of the cutting
height. In Experiment II post-grazing samples contained as much
as 41% root contamination. The method used is probably not the
answer to this sampling problem but the figures laboriously derived
are considered to reflect quite closely the amounts present. Any
bias would probably be an over-estimation of herbage residues in
these plots rather than an under-estimation. The difficulty in
cutting to an even stubble height when defoliating to ground level,
particularly in 'pugged' conditions, would also be reflected in
higher post-grazing D.M. yields. It has been observed that there
is a natural tendency to leave more stubble when pasture is long
than when it is short (Bone and Taylor, 1959; Scoffield, 1970). A
conscious effort was made to avoid any such bias.

In measuring D.M. production over the regrowth period
there is the problem of sampling a dynamic situation. The 10
day harvest data measure a nett D.M. production; the balance
between growth and decomposition. This is particularly noticeable
in Experiment II where in some cases negative growth rates were
recorded over the first 10 days of regrowth. The D.M. samples
taken fail to tell the amount of new growth that had taken place,
the contribution of the D.M. present at the previous harvest date
to that present at the next harvest or the rate of leaf and plant
death and decomposition between harvests. Samples taken do
record the available D.M. present at that time; i.e. the D.M.

that could be offered to a grazing animal should the pasture be grazed. In all except two treatments in Experiment I variability within pastures appeared to be reduced following grazing. No estimate of the within plot variation was obtained as the three samples taken per plot were bulked prior to washing.

Botanical Analysis

The method used is possibly the most accurate method of botanical separation on a weight basis used (Brown 1954), the only errors involved being in the sampling procedures adopted. Botanical samples were taken from those harvested for D.M. yields which meant only a small area of each plot was actually sampled for botanical composition at any one time. Although a more representative sample may have been obtained at each sample date if 20 small grab samples had been cut from each plot, it was thought a bias would result due to the inaccurate cutting of these small samples to ground level.

Tiller Density

A stratified random sampling was adopted in sampling tiller populations. This method was found by Mitchell and Glenday (1958) to be the most efficient statistically. The number of samples taken (20 per plot or 60 per treatment) appeared sufficient and no loss of information was evident due to the reduced sampling in Experiment I. Delaying of sampling for 7 to 10 days following grazing was successful in allowing counting of living tillers only, but the degree to which this advantage was offset by the formation of new tillers is unknown. As it has been observed (Section 1.2.1) defoliation may induce a temporary reduction in tillering and it

is thought new tiller production over this 7 to 10 day period would have been minimal.

5.2   Experiment I

Significant results obtained and trends shown in Chapter III will be discussed in this section and also in a combined discussion with those from Experiment II in Section 5.4.

D.M. utilization and intake

In early June intake of dry cows can be restricted and animals held to constant weights (Section 1.4.3). This would mean cows require a maintenance requirement only with a small addition for pregnancy. In practice the increase in weight due to pregnancy is often cancelled by a weight decrease in the cow to give an overall constant weight. Maintenance figures given by Hutton (1962) for dry cattle held to constant liveweights (Table VI) are probably the best estimates available for this situation.

The average cow (722 lb) would require 8.37 lb D.M.daily for maintenance. Allowing the commonly adopted 30% increase for the outdoor environment (Section 1.4.2) this requirement increases to 10.88 lb D.M. per cow per day. A possible addition of 2 lb D.M. per day would be required for pregnancy (Table VII). As set out in Table X all treatments gave intakes below 12.88 lb D.M. daily. This puts a query on the use of the 30% outdoor loading in this situation as cows at the lowest intensity, though restricted, rejected more herbage (Figure 11) and grazing residues were 80% more than those left by cows at 200 cow days per acre. Probably all that can be suggested is that at 120 cow days per acre cows were at or above maintenance and those at 200 cow days per acre slightly below

maintenance. Grazing duration had little effect on intake; the difference between extremes being only 1.79 lb D.M. per cow per day.

Cows in the '72 hour' treatment did not appear to suffer the same daily nutritional stress as the on/off grazing of the '6 hour' or to a lesser extent the '24 hour' treatment. Possibly the '72 hour' grazing treatment would involve a lower maintenance requirement for the animals than the other grazing durations.

Despite a 31% reduction per cow per day in intake at the high grazing intensity, the increase in grazing intensity resulted in the cows having a highly significant increase in the percentage utilization of available D.M. (12.3 percentage units) compared to the 120 cow days per acre treatment. The utilization figures recorded, of over 80%, are higher than those obtained by Campbell (1966) at Ruakura with controlled grazing over the winter period at 1.2 cows per acre. Campbell achieved values of only 55% to 70% over a three year period in spite of a possible overestimation of utilization by using electric hedge trimmers which fail to sample to ground level.

Cows grazed at 200 cow days per acre generally left residues of under 400 lb D.M. per acre; the lowest being only 289 lb D.M. per acre (at the '24 hour' grazing duration). These low residues reflect the ideal environmental conditions and the grazing pressure over the experimental period (Appendix 1). Grazing pressure was a parameter proposed by Mott (1960) to relate grazing intensity in terms of pasture availability for the comparison of stocking rate treatments. Grazing pressure

as used in this text is defined as :

$$\text{Grazing pressure} \;=\; \frac{\text{grazing intensity (cow days/acre)}}{\text{Herbage available (DM/acre)}} \times 100$$

'24 hour' grazing gave the highest percentage utilization but did not show the highest daily intake. This was probably due to the lower amounts of D.M. available before grazing on the '24 hour' than both the '6 hour' and '72 hour' treatments (Table XI) resulting in different grazing pressures being applied within each duration. Grazing pressures are presented in Table XLIV and show the '6 hour' and '72 hour' treatments to have 6.5% and 16.8% lower grazing pressures than those in the '24 hour' duration.

TABLE XLIV : <u>Experiment I – Grazing pressure and actual and corrected Post-grazing D.M. residues</u>

	Grazing intensity (cow days per acre)		Grazing duration (hour)		
	120	200	6	24	72
Grazing Pressure	5.5	9.4	7.5	8.0	6.6
Post-grazing DM (lb/acre)					
Actual	671	395	590	429	574
Corrected	667	394	589	419	591

Covariance analysis for these differences in pre-grazing D.M. yields had small influence on post-grazing D.M. residues (Table XLIV) and consequently little effect on D.M. intake and percentage utilization figures.

Grazing activities (i.e. standing, grazing or lying) were recorded at 20 minute intervals for all animals on '6 hour' and '24 hour' grazing durations during grazing on Day 3. No differences were observed between treatments; over the 6 hour period most

cows grazed continuously. The reduced grazing period increased the grazing residues by only 161 lb D.M. per acre.

The movement in intakes and utilization are much as expected in terms of pasture availability, animal demand, selectivity and grazing characteristics discussed in Section 1.3.1 and 1.3.3. Herbage rejection around dung pats was greatest at the lower intensity and the shortest duration (Figure 11). Even at the highest grazing pressure cows preferred to reject small amounts of herbage around dung pats. The extreme values recorded were 82.2 and 14.8 lb D.M. per acre for the 120 – 6 hour and 200 – 24 hour treatments respectively. Expressed as a percentage of the residue left between dung sites, the figures become 11.2% and 5.1%. Differences in rejection appeared visually to be more pronounced than in actual measurement. In the '72 hour' duration treatment rejection around dung sites was more noticeable than for the '24 hour' but less than the '6 hour' treatment. Rejection in '6 hour' grazing was around old dung sites whereas most rejection in the '72 hour' was around dung voided during grazing.

D.M. losses under dung voided in the course of grazing were not measured with the mowing technique used, but this bias was probably more important in the '72 hour' than the remaining treatments. Such loss of pasture would be reduced in the '6 hour' duration as the cows were removed for 75% of the time, in the '24 hour' as most grazing occurs in the first 6 hours and in the '72 hour' as only dung voided in the first two days will be a source of rejection. Over the grazing period only 3.9% and 5.5% of the pasture would have been covered by now dung in the low and

high intensities respectively (Section 1.3.3). The loss from this source will consequently be small.

D.M. Regrowth

Two main effects dominate D.M. regrowth yields (Table XI).

(i) The lower D.M. production at 200 cow days per acre compared with 120 cow days per acre grazing intensity.

(ii) The lower D.M. production after '24 hour' grazing relative to '6 hour' and '72 hour' grazing durations.

Although the high grazing intensity significantly reduced D.M. yields at all stages of regrowth, the initial difference of 276 lb D.M. per acre between grazing intensity treatments at the post-grazing harvest had increased only slightly in real terms 60 days later when the difference was 389 lb D.M. per acre. The difference in average growth rates for the 60 day period between grazing intensities amounted to 1.9 lb D.M. per acre per day. Over both intensities the average rate of growth over the 60 day period was 19.0 lb D.M. per acre per day with the highest values achieved over any 10 day period being 29.6 lb D.M. per acre per day between the final two harvests. These figures compare with those achieved at Palmerston North over the winter period by Brougham (1956 b) for a pasture defoliated on 3 June and growth measured over the following nine weeks. Brougham obtained an average growth rate of 20.1 lb D.M. per acre per day but from a more lenient defoliation system. Relative growth rates between day 10 and day 60 were significantly higher on the 200 cow days per acre treatment because of the lower quantity of D.M. present at any one time on plots of this treatment.

Residual leaf areas (RLA) following grazing were probably higher in the low than the high intensity treatment because the increased post-grazing D.M. yields on this treatment. Despite an increase in the percent dead matter at the high grazing intensity, in absolute terms there was a higher yield of dead matter in the low intensity. These equated to give an initial difference of 237 lb green D.M. per acre. In terms of LAI, this difference could amount to approximately 0.5 of an LAI unit (Brougham 1958).

The increase in dead matter after grazing is not thought to be the result of plant death due to grazing but rather to the technique used and to animal selection against dead matter. Quantities of sheath and stem material were possibly classified as dead following grazing whereas previously these had been attached to larger green units of plant and classified as live material.

Due to the exponential nature of regrowth it could be expected that the higher initial leaf area on the low intensity plots would lead to greater differences than were found in the later regrowth. Botanical composition cannot be put forward in way of explanation as no significant differences appeared between treatments (Section 3.1.5). A similar situation existed with the soil measurements, viz. moisture (Section 3.1.9) and soil bulk density (Section 3.1.10). It is possible that the difference in leaf area was insignificant as 0.5 LAI units is much smaller than differences generally imposed between treatments in experiments studying LAI and defoliation treatments. The difference amounts to 13.9% of the leaf area required to intercept all incoming light at this period (Brougham 1958). Ground cover differences

between the high and low intensities were small; 73.2% and 84.8% respectively. Though highly significant, in terms of light utilization at that time of the year the difference in ground cover was probably not important.

Prior to grazing tiller numbers per ft^2 were high, viz. 736 ± 19.9 grass tillers per ft^2. This is somewhat high for dairy pastures and is more consistant with those recorded on closely grazed sheep pastures (Mitchell and Glenday, 1958). As might be expected at this time of the year there appeared to be a distinct hierarchy within the total grass tiller populations. It involved mature tillers of established plants, new tillers formed a the base of such plants, and new single tiller seedlings. The last named were the most prevalent in number, forming a dense mat at the base of the sward and were apparently the result of two factors:

(i)   Seeding associated with the late hay crop.

(ii)   Invasion of Poa species after a dry autumn (Appendix 1).

Seedlings were predominantly of ryegrass and Poa species (viz. Poa anmua).

Regardless of treatment tiller numbers decreased markedly over the regrowth period and by 19 August densities were only 56% of those present 10 weeks before. This reduction was probably due to the death of young seedlings attempting to establish within an established pasture. Competition would exist for light (Donald, 1963) and for soil nutrients (Wilkinson and Gross, 1964) thereby affecting both root growth and leaf growth of the seedlings.

Grazing at 120 cow days per acre had little immediate effect on tiller populations but increasing this intensity to

200 cow days per acre markedly reduced tiller numbers (Figure 9).
Ryegrass tiller populations were affected by both grazing durations
while Poa species showed a decrease with grazing at the high
intensity and a continued increase at the low intensity.

Despite the reduction in tiller populations at the high
grazing intensity the values still remained high (554 $\pm$ 42.0 tillers/
ft^2). The reduction was mainly in the seedling component due to
increased pulling of young plants and increased hoof damage.
However being the smallest tillers present, they were probably
also the least productive fraction of sward and could have resulted
in a strengthening of the remaining tillers.

As with grazing intensity, differences in D.M. regrowth
between grazing duration tended to remain similar throughout the
regrowth period (Table XI). The exception was the decline of the
'6 hour' treatment during the latter stages of regrowth. This
decline was more marked at the low intensity and was reflected in
the lower relative growth rates for the '6 hour' grazing treatment,
particularly at the low grazing intensity (Table XIII).

In terms of grazing residues, the difference between extreme
values for grazing durations amounted to only 120 lb green D.M. per
acre, roughly half that present between grazing intensities.
Grazing duration had small effects upon all measured soil and pasture
parameters. The same arguments advanced for the greater relative
growth rate in the high compared to low grazing intensity could
also be advanced for the greater relative growth rate in the '24
hour' grazing treatment. Within grazing intensities tiller populations
were reduced more with a '24 hour' grazing duration than with either

a '6 hour' or '72 hour' duration.

The higher dead matter figure in the '72 hour' grazing duration is probably due to he higher residues left after grazing and to the greater time afforded the cows to graze selectively in comparison to the '24 hour' and '6 hour' treatments respectively.

As a constant relationship existed between duration treatments in tiller populations, the relative decline in D.M. production of the '6 hour' duration must have been associated with tiller vigour. Three possible reasons may be proffered:

(i) Tillers may have been subjected to increased competition, earlier in regrowth. This is not supported however by changes in tiller populations, but competition for some factor may possibly have occurred as the decline noticeably affected the low grazing intensity earlier than the high grazing intensity.

(ii) The high grazing intensities used mean that urine return may have covered much larger areas of pasture than is normally the case (Section 1.3.3). Using figures quoted in Section 1.3.3 urine could have been excreted on 11% and 18% of the total area when grazed at 120 and 200 cow days per acre respectively. Various estimates for the area of pasture responses to a urine patch have been made, from that actually covered by the urine spot (Norman and Green, 1958) to an area 3 times the size (Lotero et al. 1966). This spread will depend on soil moisture, soil type and texture, and slope (Section 1.3.3). These estimates

would give pasture responses to urine on areas
upward to 33% and 55% at the grazed area in the
120 and 200 cow days per acre plots respectively.
With '6 hour' grazing these figures would be reduced
to one quarter. No evidence is available on the
distribution of dung and urine throughout the day
following restricted grazing. If not uniform, it
it is likely the '6 hour' plots would be further
prejudiced at a time when N responses were high.

(iii) As a result of selective grazing , the variability within
the '6 hour' grazing duration plots appeared much larger
than in any other treatment. This was particularly
evident at the low intensity. As a result accurate
sampling of these plots may not have been achieved with
the intensity of sampling used.

Defoliation Treatments (cut v's grazed)

The comparison between defoliation treatments in this
experiment is somewhat obscured by there being no post-defoliation
samples taken from the control (non-grazed) plots. From the trends
between day 10 and day 20 (Figure 13) it appears that residues may
well have been in the same order on cut and grazed plots or perhaps
higher on the cut plots, especially at the low intensity. This
makes discussion of absolute D.M. production somewhat more difficult.

Control plots immediately after defoliation had a faster rate
of growth than grazed plots, but this appeared to decline after
day 20 for the low intensity and day 30 for the high intensity

treatment. It would appear that grazing hindered early growth relative to cutting but the disadvantage was short lived. This increased growth on cut plots was evidenced by increased ground cover as a result of less seedling damage and possibly higher residues. Consequently large increases were recorded in the Poa component both in terms of D.M. yield (Figure 14 and 15) and tiller populations (Figure 17). Tiller populations of Poa species increased in cut plots until by 19 July 261 more tillers per ft^2 were recorded in the cut than grazed plots. Over the last month however tiller death was more pronounced in cut plots (Figure 17b). The contribution of Poa tillers to D.M. yield on cut plots can be visualized; Poa tillers outnumbered those of the total sown species, but Poa species produced only 20% of the D.M. yield and the sown species 60%.

Between defoliation intensities the treatments acted similarly in almost all measurements made except ground cover and ryegrass tiller populations.

Competition in cut plots could be the cause of the decline in the growth rate, this being strengthened by the fact that the decline occurred earlier in regrowth at the low defoliation intensity. The argument presented previously with respect to urine return in the '6 hour' grazing duration would also apply in any comparison between the cut and grazed treatments.

It is difficult to offer a satisfactory explanation of the high D.M. yields at day 60 on the control plots relative to those recorded at previous harvests (Figure 13). The more productive ryegrass species possibly by this stage were suffering less

competition from <u>Poa</u> species and consequently could take
advantage of the climatic environment. Visually it appeared
that this increase was real as control plots appeared to 'improve'
over the latter stages of regrowth.

Section 3.3 also shows several other differences arising
from defoliation treatment.

(i) Dead matter increases following defoliation were more
pronounced in grazed plots (Figure 15) due to the
unselective nature of the mowing technique and also
to reduced plant damage through pulling and leaf
damage.

(ii) The elimination of the grazing animal initially
enhanced clover yield and populations but the
difference soon disappeared.

(iii) Defoliation treatments had little effect on tiller
populations of the sown grass species (Figure 16).
Ryegrass (Table XXI) was favoured by grazing at the
high intensity, possibly through the elimination of
competition from <u>Poa</u> species when plots were grazed
rather than cut.

(iv) Soil moisture (%) were higher in control plots early
in regrowth. The difference was never great and
disappeared after 2 months. It was probably due to
the lower bulk densities and increased ground cover
in the control plots.

(v) Grazing appeared to have little effect on the
bulk density of the top 3 cm of the soil but
appeared to increase densities in the 3 – 9 cm
region. The differences were however small and
unlikely to have effected production or soil
moisture retention (Section 1.3.2). Differences
immediately following grazing may have been
greater than those recorded but no long term
changes resulted.

5.3   Experiment II

D.M. Utilization and intake

i. Grazing durations v's grazing intensity

As a result of low growth rates prior to grazing available
D.M. was below that desired for experimental purposes and less than
that present in Experiment I. It was thought desirable to operate
the trial as in Experiment I so no hay was fed despite all cows
being below maintenance.

D.M. availability (Table XXVI) prior to grazing were only
in the order of 1500 to 1600 lb D.M. per acre which meant that at
the most, if utilization was 100% the intake at the lowest grazing
intensity would be 13.3 lb D.M. per cow per day and at the highest
intensity 8 lb D.M. per cow per day.

The average estimated intake per cow per day was 6.60 $\pm$
0.25 lb D.M. Between treatments however the greatest difference
was due to grazing intensity. Cows at 120 cow days per acre had
intakes of 8.54 lb D.M. per day and at 200 cow days per acre 4.67 lb

D.M. per day. Maintenance for the average cow (808 lb) would amount to approximately 14.93 lb D.M. per cow per day, as calculated from Hutton's figures (1962) and adding a 30% increase for the outdoor environment (Section 1.4.2) and 3.1 lb D.M. per cow per day for pregnancy (Table VII). This figure of 14.93 lb D.M. per cow per day is well in excess of figures achieved during the experiment. Cows at the low intensity received 57.2% of this requirement and those at the high intensity received only 31.5%.

Grazing pressures presented in Table XLV are much higher than those in Experiment I (Table XLIV) and reflect the low available D.M. at grazing.

TABLE XLV : Experiment II – Grazing pressures of grazing intensity and grazing duration treatments.

		Grazing Pressure			Grazing Pressure
Grazing intensity	120	7.5	Grazing duration 6		11.1
(cow days/acre)	200	13.2	(hours)	24	9.6
				72	10.3

The significant difference in intake shown between cows grazing '6 hour' and '24 hour' durations is due entirely to an increase of 226 lb D.M. per acre on '24 hour' plots before grazing (Table XXVI). Post-grazing D.M. yields were adjusted by co-variance analysis for differences existing before grazing but had small effect on intake values. It is probable that such analysis is not biologically justified as underfeeding was of such a degree that the differences in available D.M. prior to grazing would

have little effect on the residues left after grazing.

Grazing pressure was such that all animals on all treatments defoliated pastures to the maximum level possible, hence giving rise to no differences in the percentage utilization of the pasture. The extreme values reported, those for the '6 hour' and '24 hour' treatments were a function of variability before grazing rather than after grazing.

Percentage utilization figures in the order of 60%, are low, as the low available D.M. per acre meant a high proportion of D.M. present was below the grazing height of the animal. After grazing animals on all treatments left in the vicinity of 570 lb to 590 lb D.M. per acre – giving rise to a more or less uniform defoliation treatment across all plots, but owing to the differing grazing durations and intensities imposed the damage imparted in performing this defoliation obviously varied.

ii. Between Day

The soil was at field capacity before the experimental grazing and as a result of overnight rain surface water lay on all plots when the animals were introduced on Day 1. Surface moisture had disappeared by Day 2 and Day 3.

Increased surface damage occured visually in plots grazed on Day 1 compared with other days. This supports Edmonds (1966) observation that damage will be reduced if grazing is delayed for even a few hours following rain. It was thought intake on Day 1 may have been restricted relative to the remaining two days. Figure 26a shows a trend toward lower intakes on Day 1 but amounts to only a reduction of 1.01 lb D.M. per cow per day at the low

intensity and 0.45 lb D.M. per cow per day at the high intensity;
a reduction of 11.2% and 9.5% respectively. The reduction was
greatest, both in absolute and relative terms, at the low grazing
intensity. This could have been the result of greater nutritional
stress at the high intensity meaning consumption was more rapid and
took place prior to pasture damage, and/or these animals were
more prepared to consume soiled herbage. Such observations should
be viewed with caution due to the lack of statistical significance
between results.

Percentage utilization figures (Figure 26b) follow a similar
trend to those of D.M. intake but as with intake measurements no
significant results were recorded between days.

iii. Defoliation Treatment

Cut plots did not show the same variation in 'equivalent'
intake per cow per day (Table XXXVIII), this being a reflection
of the differences in defoliation residues due to the inability of
the cutting techniques to simulate the grazing intensity. Between
defoliation intensities there was only 6 lb D.M.per acre between
residues when grazed but in the non-grazed plots the difference was
270 lb D.M. per acre.

Cutting at the high intensity underestimated residues from
grazing by 110 lb D.M. per acre while at the low intensity it was
overestimated by 166 lb D.M. per acre. This gives rise to the
differences in intake and percentage utilization shown between
defoliation treatments in Table XXXVIII.

It is interesting to note that the highest utilization was

recorded by mechanical methods which at the high intensity left residues of 472 lb D.M. per acre. Values of this order could not be achieved with farm scale mechnical harvesting owing to soil moisture status and its inability to withstand heavy loads.

D.M. Regrowth

i. Grazing duration v's grazing intensity

The main point to emerge from D.M. regrowth is the inter-action between grazing intensity and grazing duration.

(a) Grazing intensity caused differences in D.M. regrowth within the '6 hour' and '24 hour' durations but not the '72 hour' duration Table XXVIII.

(b) The inferiority of the '72 hour' treatment at the low intensity and the '24 hour' at the high grazing intensity.

Differences in post-grazing D.M. yields were small and non-significant. Despite this uniformity of yield, 50 days later the greatest difference between treatments amounted to 1007 D.M. per acre.

Herbage present at the post-grazing harvest did not contribute equally to future production. This was due to varying degrees of damage having been inflicted by the different grazing regimes, through burial, displacement and dismemberment of leaves, tillers and plants. Damage was difficult to assess visually as in the '6 hour' and '24 hour' durations the damage is the mean of three separate days.

Damage is reflected in the growth rates immediately following

grazing when negative rates were achieved by all 200 cow days
per acre treatments and on the '72 hour' duration at 120 cow
days per acre (Table XLVI). These differences were such that
10 days following grazing highly significant differences existed
between treatments in D.M. yield.

TABLE XLVI : Experiment II – Grazing duration and grazing intensity
effects on regrowth for the first 10 days following
grazing (lb D.M. per acre per day).

	Grazing Duration (hours)		
	6	24	72
120 cow days per acre	8.0	1.0	−3.0
200 " " " "	−2.1	−16.1	−13.6
S.E. mean +		11.26	
L.S.D. (0.05)		3.65	

Using this initial regrowth as criteria for damage at
grazing, those treatments suffering the greatest damage were those
giving the lowest regrowth yields after 50 days growth.

Relative growth rates show that between grazing intensities,
within grazing durations, growth was proportional to that present
at any one time. As the '72 hour' treatments differed by only
6 lb D.M. after day 10 no differences resulted over the remaining
regrowth period. Within the '6 hour' and '24 hour' grazing
durations absolute values were greatest at the 120 cow days per
acre intensity as it had significantly higher quantities of D.M.
at day 10.

It would appear that all differences had taken place by

day 10 and that regrowth after this stage was proportional to
the quantity of D.M. present at day 10. There was no measure
of pasture death, growth or survival over the initial 10 days
of regrowth. The low intensity reduced total grass tiller
populations by 13% over this period while the high intensity
brought about a 36.7% decrease. Unsown grass species decreased
to a greater extent relative to sown grass species in the 120
cow days per acre than the 200 cow days per acre treatment. This
was reflected by an increased contribution of total sown grass
species to D.M. yield at the low grazing intensity. Reductions
in tiller populations gave differences between intensities of a
similar order to those in D.M. production, the ratio being 1 : 0.93.
Yield differences between grazing intensity appeared to be due
to tiller numbers rather than differences in yield per tiller.
At this stage regrowth was dependent on the number of growing
sites per acre rather than the rate of growth at each site. This
position gradually changed till at the final harvest a difference
of 602 lb D.M. per acre existed while tiller numbers were constant.
The yield per tiller was greatest in the 120 cow days per acre
treatment as a result of the death of presumably the low producing
tillers in this treatment. Inter-tiller competition would be
reduced owing to improving climatic conditions in terms of light
and temperature but enhanced by deteriorating moisture conditions
over the regrowth period (Appendix 1).

Between durations a different situation existed, the '6
hour' treatment having the greatest nett balance in D.M. to day 10
after which the rate fell relative to other treatments. As the
'6 hour' treatment suffered no reduction in tiller numbers relative

to other treatments, reduced growth rate was presumably associated with reduced tiller vigour. The return of nutrients through urine deposits would play a similar role as discussed in Experiment I (Section 5.2). A decrease in the contribution of ryegrass and other sown grasses to D.M. yields in '6 hour' relative to '24 hour' and '72 hour' durations would lend support to their argument.

Tiller numbers were reduced 38% and clover nodes 47% by a '24 hour' duration immediately following grazing, compared with figures at 18% and 20% for '6 hour' and 22% and 27% by the '72 hour' treatments. At the high grazing intensity the reduction in tillers due to intensity itself plus that due to the 24 hour grazing period gave low tiller populations on this treatment. Although the relative growth rate of this treatment was the highest of all treatments the initial reduction in D.M. yield ensured that the treatment retained lowest production ranking. The improved growth rate was probably due to a lack of competition and to the suggestion that tillers remaining at day 10 were higher yielding than those of other treatments.

Soil bulk density showed a tendency to increase in the top 0 — 3 cm layer at the high intensity but more specifically at the '24 hour' duration. This tendency to increased surface compaction was small, but differences may have been more substantial immediately following grazing. This small shift was associated with surface crusts in some '24 hour' plots which showed reduced infiltration following rain.

ii. Between Days

The main feature in D.M. yields was the inferiority of
Day 1 plots especially at the highest grazing intensity with a
'24 hour' grazing duration. Over the pre-treatment period 1.41
inches of rain were recorded with 0.47 inches of this falling
overnight immediately prior to grazing. As a result soil was
saturated with pools of water present in most plots when the
animals were introduced to plots on Day 1. Except for 0.05 inch
on the final night no further rain fell over the experimental
period. Visual damage through pugging and puddling appeared
most severe on Day 1 in all treatments compared with the remaining
two days.

Visual differences were not reflected in terms of significant
D.M. differences except in the 200 cow days per acre - 24 hour
duration treatment. An average reduction of 17.2% in D.M.
production was recorded at all regrowth harvests for this treatment
on Day 1 compared to the mean of the other two days. All other
treatments showed a reduction with the corresponding figures being
5% for the remaining high intensity treatment and for the low
intensity, 9.5% for '24 hour' and 1.3% for '6 hour' grazing. In
absolute values the relative decrease being 1 : 0.33 : 0.74 : 0.11
for the treatments as named.

Greatest damage was at 200 cow days per acre for 24 hours;
reducing the grazing duration had a greater effect on reducing this
loss than did on easing of the grazing intensity.

In contrast to D.M. regrowth, differences between days
in grazing residues were not significant but there was a trend to

higher residues on Day 1 plots, compared with mean values for Days 2 and 3, in all treatments. Regrowth over the first 10 days (Table XLVII) tended to reverse this trend but differences in yields were still non-significant between days.

TABLE XLVII : Experiment II - Between day effects on regrowth for the first 10 days following grazing (lb D.M. per acre per day)

| | Grazing intensity (cow days/acre) | | | |
| | 120 | | 200 | |
Intensity	6 hour	24 hour	6 hour	24 hour
Day 1	5.6	−1.9	−11.8	−33.8
Day 2	17.8	7.7	3.8	− 6.8
Day 3	0.5	−2.5	1.7	− 7.5
LSD (0.05)	21.5			
S.E. mean ±	7.17			

The absence of significant results at the 10 day harvest and the small differences in most treatments later in regrowth are reflected in the relative growth rates. Analysis of b values showing no significant differences between days.

The decrease in production on Day 1 at 200 cow days per acre - 24 hour treatment was associated with a drop in tiller densities between 8 August and 24 August. Only in this one treatment were differences substantial, the decrease after grazing being 23 percentage units greater in Day 1 plots than for the remaining days. Similar trends were shown in all species. The reduction in tiller numbers was greater than that in D.M. production so presumably the smallest lowest producing tillers were destroyed; this would also contribute to the increased relative growth rates on these

plots.

Decreases in D.M. yield and ryegrass contribution in
Day 1 plots late in regrowth may possibly be due to increased
soil bulk densities and to the formation of surface crusts
affecting aeration and moisture availability of the top inches
of the soil. Surface crusts were most evident in the lowest
producing treatment, no differences however were measurable in
soil moisture percentages between days in the top 4 inches.

iii. Defoliation Treatment

Control (non-grazed) plots had consistantly higher D.M.
yields than the grazed treatments throughout the regrowth period.
The difference however all took place during defoliation and the
first ten days of regrowth. After this point the two treatments
ran parallel.

There is difficulty in interpretation due to the different
residues and hence intensity of defoliation applied. Grazed plots
had similar residues whereas cut plots differed by 276 lb D.M.
per acre between defoliation intensities. This difference however
did not result in increased growth rates at the higher value.
Little or no damage occurred to plants with mechanical harvesting
whereas in grazed plots this was not the case. For example, a
growth rate over the first 10 days on cut plots was 35.8 lb D.M.
per acre per day compared to a decrease of 4.3 lb D.M. per acre
per day on grazed plots. This difference was accentuated at the
high intensity due to lower growth rates on the grazed plots
(Table XLVIII).

TABLE XLVIII : Experiment II - Defoliation treatment effect
on D.M. regrowth over the first 10 days following
defoliation (lbs D.M. per acre per day).

	Defoliation intensity (cow days/acre)	
	120	200
Cut	36.8	34.8
Grazed	2.0	-10.6
LSD (0.05)	6.6	
(0.001)	16.0	

Large differences were recorded in tiller populations
over this initial period. After ten days cut plots had 72%
more clover nodes and 60% more grass tillers per ft^2 than
grazed plots. Both sown and unsown grasses showed similar
trends but within the unsown components the increase was mainly
Yorkshire fog. Tiller numbers did not account for all differences
in yield as production per tiller was also lower on grazed plots.

Although grazing hindered early growth relative to cutting
this disadvantage was short lived. Despite having 80% higher D.M.
yields at day 10, the cut plots had this increase trimmed to 14%
by the final harvest. These changes were reflected in much lower
relative growth rates on cut than grazed plots. The higher
densities on cut plots would probably increase inter-tiller
competition on these plots, a situation evidenced by increased
rates of tiller deaths in cut plots early in regrowth. Tiller
productivity also decreased in cut plots especially in the ryegrass
component. The increase in the more prostrate Yorkshire fog species
in cut plots would also increase competition and lower productivity.

As discussed previously the lack of urine return would also act against cut plots. It appeared that grazing through removing large numbers of tillers enhanced regrowth on a per tiller basis for the remainder of regrowth period and established an improved composition over cut treatments. Ryegrass species were enhanced both in population and productivity by grazing, this being most noticeable when cut plots were leniently defoliated.

5.4   When discussing the implications of these results, it must be borne in mind that these experiments were carried out on only one soil type and in one season. Weather conditions over the winter period (June - August) were drier and cooler than average (Appendix 1). Rainfall over the 3 month period was 3.9 inches less than normal. Regrowth in September was enhanced by warmer than average mean daily temperatures $(+ 3^{o}F)$.

The greatest variable in wintering dry dairy cattle, in terms of estimated D.M. 'intake' and subsequent D.M. regrowth, is grazing intensity. In all measurements grazing intensity gave rise to larger differences than either the method of grazing or differing environmental conditions between days.

Under conditions of low D.M. availability, animals have been able to compensate to some extent for the increasing feed shortage and grazing pressure by increasing the proportion of available D.M. harvested - through increasing grazing time and decreasing their selectivity in grazing (e.g. Arnold, 1964). In this study this was evidenced in the June but not the August grazing. Only in the ideal grazing conditions experienced in

June were cows at the high grazing intensity able to markedly increase 'utilization' over those at the low intensity. For example, the 67% increase in grazing intensity gave only a 31% decrease in estimated daily intake. In adverse conditions the animals appeared unable to increase utilization and grazed to a constant height. In June grazing residues of below 400 lb D.M. per acre were obtained whereas in August, despite a 42% increase in grazing pressure, residues were increased by 50%. Some of this difference probably originated from differences in pasture composition and strucuture but it is likely that the main component was the physical difficulty in harvesting as a result of pasture damage, soil contamination and burial.

Estimated 'intakes' in Experiment II were therefore low due to low D.M. availability on one hand and to greater grazing residues on the other. To this extent Experiment II was unrealistic as animals were estimated to be considerably below maintenance 'intakes'. Something in the order of 6 lb D.M. and 10 lb D.M. as hay would have been required at the low and high grazing intensity respectively to bring intakes to around maintenance. It is possible that feeding supplements could affect grazing damage in either direction; reduced grazing pressures reducing pasture damage (120 cow days per acre c.f. 200 cow days per acre in both experiments), or feeding supplements on pasture already pugged could cause additional pasture damage. Campbell (1966 b) observed that less damage occurred when a given grazing intensity was spread over two days, and supplements fed on the second day, than if the grazing intensity had been reached in one day on grass alone.

The manner in which pasture was grazed within each intensity had small effect on estimated D.M. 'intake' and 'utilization'. Although interpretation is somewhat clouded by differences in grazing pressure between treatments within each experiment, there was a suggestion of greater 'utilization' and 'intake' with '24 hour' grazing. The '6 hour' treatment had the lowest intakes, though the average reduction in both experiments was only in the order of 1 lb D.M. per cow per day.

Environmental conditions between contiguous days appeared to have only small effect on the animals ability to harvest available D.M. In the adverse conditions experienced on the first day of the August grazing, estimated 'intake' was reduced by 10% over that on the two following days. It appears that differences will only occur when very wet conditions apply at the time of grazing. Over a longer period of time where pasture and soil properties are subject to change (e.g. Experiment I compared with Experiment II) the differences may be greater.

By the final regrowth harvest, in both experiments, D.M. production at the lower intensity was approximately 25% greater than that resulting from the high grazing intensity. In terms of time, if pastures were grazed when 2,000 – 2,500 lb D.M. per acre was present, this difference would mean in Experiment I that pastures could be grazed twelve days earlier following the low intensity grazing than the high intensity treatment; while in Experiment II, due to increased growth rates, only six days earlier. This increased growth at the low intensity would compensate for some, but not all, of the extra land needed over

the wintering period when the lower grazing intensity is used.

D.M. regrowth following the early winter grazing was slower than that in August. It is possible that pasture damage, such as occurred in Experiment II, at this early stage of the winter would mean recovery would also be slower, putting an area of land 'out of action' for longer periods. As a result it may therefore have a greater effect on the post-calving feed supply than indicated by the data in Experiments I or II. Such conditions would also allow the ingress of volunteer grasses in bare ground.

Volunteer grasses did not increase in contribution on heavily trodden pastures in this study. For example in the first experiment (June), although growth was slow, damage at grazing was not immense and pastures still remained reasonably dense with adequate ground cover. In the second experiment (August) although pastures became more open as the result of damage at grazing, regrowth from the remaining established tillers was probably fast enough to increase ground cover and suppress volunteer seedlings. The formation of surface crusts in soils of the worst treatments and declining moisture conditions probably also worked against volunteer species. It was only in treatments showing least grazing damage in the first experiment that the unsown grass species increased to any extent — this probably being the result of Poa seedlings surviving grazing rather than any marked ingression of new germinating seedlings. In fact, the most significant level of volunteer grasses (e.g. Poa species) occurred in the mown plots, which lends support to the above statement and to the observation made by Sears in 1962.

Weeds formed only a minor component in both pastures and

this appeared unaltered by grazing treatments.

In the discussion of each experiment (Section 5.2 and 5.3) tiller populations have been put forward as the main determinant of difference in D.M. regrowth following grazing. The basis of tiller changes appears however to differ between the June and August grazings.

i.   With the high initial tiller populations present in Experiment I, despite the large reductions from high intensity grazing, tiller populations remained relatively high (above 500 per ft^2). It is suggested that the reduction was mainly in the small seedlings and lower producing tillers leaving a smaller number of larger tillers in these pastures compared with those grazed at the low intensity.

ii.   In Experiment II tiller numbers were lower, more in the order of those present at the end of Experiment I than at the beginning. Since the Autumn, pastures had been grazed heavily in April and again in early June and indications from Experiment I would suggest that following such management tiller numbers would be more stable by this time. This is supported by the fact that tiller reductions in Experiment II equalled D.M. reductions, there appearing to be no differential removal of low producing tillers. Following grazing at 200 cow days per acre pastures therefore contained fewer tillers than if grazed at 120 cow days per acre but these tillers did not differ in size.

Why, therefore, were differences in D.M. production of a similar order at the end of each experiment. In June, it appeared that high tiller populations following grazing at the low intensity

probably led to increased competition and tiller death, restricting
the production per unit D.M. present. By comparison, tillers in
the high grazing intensity treatment were at least able to produce
at maximum levels within the environmental limits imposed. In
August competition would appear to be absent initially on all
plots and production per unit D.M. accrued at similar rates
following the high and low grazing intensities. The low grazing
intensity treatments suffered less damage at grazing in Experiment
II, than high grazing intensity treatments, the former showing
nett D.M. gains over the first ten days of regrowth and the latter
D.M. losses. Reduction in tiller numbers in this experiment seemed
less clear cut than in Experiment I. Although substantially reduced
follow ng grazing, the populations became better defined at the
third sampling date (35 days after grazing) as evidenced by the
increased levels of significance obtained for the smaller absolute
differences recorded between grazing intensity treatments at this
time. This was possibly due to changes in tiller populations
within each grazing intensity, i.e. increased tiller damage and
lower tiller densities at the high grazing intensity may have led
to an increased turnover in tillers and therefore to younger tillers
on these treatments. This would support the idea that herbage on
poached plots is at a younger stage of growth than that from
unpoached plots (Section 1.3.2.). Langer (1958) has shown that
often recorded fluctuations in tiller numbers do not reveal the
dynamic changes of continuous tiller death and tiller formation
that may be occurring within a pasture.

Improved relative growth rates on high intensity plots in
Experiment I and on badly damaged plots in Experiment II did not

however compensate for the lower initial values caused by increased 'utilization' and/or damage at grazing.

Although grazing intensity caused the major effects, differences were also caused at various times by the grazing duration adopted. In the June grazing, differences in relative growth rate due to grazing duration appear to reflect variations in grazing residues rather than changes in tiller populations. Increased treading damage may have occurred in the '24 hour' duration treatments but, if present, was insufficient to alter tiller populations. The turnover of tillers, however, may have increased. The '6 and 72 hour' grazing treatments left similar residues but initially the '6 hour' treatment grew at the faster rate - possibly as a result of decreased tiller vigour at the longer duration (72 hours) from depletion of reserves caused by individual tillers being grazed periodically over the three day period. In August however, responses between '6 and 24 hour' treatments appeared related to tiller losses at grazing, this being particularly evident in grazing on Day 1. In addition to tiller losses, D.M. regrowth could also be affected by tiller damage (but not death) and mudied and buried pasture. The improved relative growth rate of the '24 hour' duration treatment possibly resulted from increased tiller turnover, as described previously for high grazing intensities. In many respects the '24 hour' treatment acted in a similar manner to an increase in grazing intensity.

In the August experiment the '72 hour' treatment was rather an enigma - little difference was shown in D.M. regrowth between grazing intensity treatments. The lack of difference was due to the inferiority of the '72 hour' duration at the low grazing

intensity rather than any great superiority at the high grazing intensity (Figure 19). At the low intensity, grazing residues on this treatment were the lowest of all recorded while at the high intensity they were the highest. Although this result is contrary to other duration treatments it possibly can be explained in terms of pasture fouling. In the wet conditions on Day 1 only one third of the total pasture was fouled in '6 hour' and '24 hour' treatments whereas in the '72 hour' treatment animals had access to the entire area. The pasture fouling in the 200 - 72 hour treatment appearing to be sufficient to increase pasture rejection. The higher negative growth rate over the first 10 days at the high grazing intensity, on the '72 hour' treatment, almost equated the differences found in D.M. yields after grazing.

The reduced tiller vigour in the '6 hour' duration treatment has been mentioned on several occasions (Section 5.2 and 5.3). Although real on a whole farm basis, losses involved would be small. Higher post grazing residues and/or lack of damage at grazing led to improved D.M. yields earlier in regrowth in both Experiments, which compensated for reduced tiller vigour late in regrowth and resulted in reductions at the final harvest of less than 3%. This reduction has been explained in terms of competition and fertility transfer (Section 5.2). Changes in tiller populations as a result of increased grazing residues and competition on these pastures are difficult to forecast as tiller numbers and competition aspects in most cases were similar for the '72 hour' treatment; a treatment not showing a similar reduction in D.M. production. The slow initial regrowth in '72 hour' treatments may have meant younger tillers on this treatment.

Unless the '6 hour' treatment has some beneficial effect on the animal, this result perhaps explains in part why on/off grazing (platform wintering) at No. 3 Dairy, Massey University, was not found to outproduce other wintering systems in terms of annual butterfat production (MacQueen,1965).

Control (mown) plots provided an interesting comparison with grazed treatments but probably is not of such importance owing to the problems that would be encountered in attempting mechanical harvesting with conventional machinery over the winter period. In all cases mown plots outyielded grazed plots, but by the final harvest the large initial difference was substantially reduced. For example, in Experiment II, the 80% greater D.M. from the mown compared to the grazed plots after 10 days regrowth, was reduced to only 14% advantage by day 50. One of the main features of the cut plots was the increase in the number of grass tiller and rooted clover nodes in comparison to grazed plots. In the June grazing this was due mainly to the failure of the mowing machine to remove Poa seedlings as well as to further ingress of Poa species during regrowth. In August all species benefited from the absence of any grazing damage. Poa species did not increase during the second experiment but there was a substantial increase in the Yorkshire fog component. Under a mowing regime, ryegrass seemed unable to compete as successfully at the low intensity as at the high intensity. The decreased growth rates recorded on the cut plots are probably attributable to increased competition through high tiller populations, increases in lower producing species, reduced tiller turnover and lack of nutrient return.

It is probable that one mowing among a series of grazings would not be sufficient to alter the production and composition of the pasture markedly. However the indications are that this may not be the case following a series of such cuts as might occur in a cut and carry management system. Differences would however be tempered by nutrient return to cut plots and seasonal pasture response.

The practical implications of this study appear to be that high grazing intensities can be used over the winter period on soils of a Tokomaru silt loam type, but that the grazing intensity used will determine regrowth regardless of the damage caused at grazing. Using a lower intensity will increase the regrowth but this will probably not compensate for the larger proportion of the farm needed for wintering and the smaller area available for post-calving feeding.

The methods of grazing as used in this study do not appear critical. In very wet conditions pasture damage is reduced by lowering the grazing intensity but a further reduction is also obtained by removing animals after short periods (4 - 6 hours). No advantage is gained from on/off grazing at other times.

One heavy grazing over the winter period with grazing intensities of up to 200 cow days per acre appear under conditions experienced in these experiments to affect D.M. 'utilization' at grazing and D.M. regrowth. Providing adequate recovery is allowed before the next grazing, it is difficult to see the changes described having a great effect on annual pasture production. The very nature of the N.Z. climate means that at times, damage

greater than that found in the present study will occur and may reach a critical point beyond which the pasture will fail to recover. It appears from this study however, that considerable damage can occur without altering the botanical composition or delaying regrowth more than a matter of a few days.

S U M M A R Y

i.   An experiment was designed to study some pasture
aspects of block grazing dry dairy cattle over the winter
period. Two grazing intensity treatments (120 and 200 cow days
per acre) and three grazing durations (6, 24 and 72 hours) were
studied. A control (non-grazed) treatment was also included.
Treatments were replicated three times and the experiment was
carried out on two occasions; first in early June (Experiment
I) and repeated in early August (Experiment II).

ii. D.M. 'utilization' and estimated 'intakes' at
grazing were measured by a series of pre- and post-grazing
pasture samples. D.M. regrowth was measured over a 60 day
period in Experiment I and 50 days in Experiment II. The
botanical composition and tiller populations of pastures were
measured at regular intervals before grazing and during regrowth.
Soil moisture and soil bulk density measurements were also carried
out.

iii. The experiments took place on one soil type, in one
season: Experiment I in fine, cold weather at a time when regrowth
was limited by environmental conditions, Experiment II in adverse
conditions, on a saturated soil, but at a time when the environment
was improving with respect to pasture growth.

iv. Experiment I : The greatest determinant of 'intake'
was grazing intensity. At the high intensity cows were able to
increase 'utilization' of available D.M. Grazing duration had a
smaller effect on the estimated pasture 'intake' and 'utilization',

the 6 hour grazing, however, gave the lowest values in both instances.

D.M. regrowth was affected more by grazing intensity than by the method of grazing, the low intensity treatment being 25% superior by the end of the regrowth period. Within grazing durations the '24 hour' grazing treatment was the lowest producing at all times and the '6 hour' treatment showed a marked decline in growth rate relative to other treatments. Control (non-grazed) plots despite lower growth rates outproduced grazed plots due to the initial inhibition of regrowth by grazing.

Most of these differences were shown to originate at the time of grazing, with the most important variable being changes in tiller populations. Grazing tended to favour ryegrass and non-grazed plots Poa species.

v.   Experiment II : Cows appeared limited in their ability to defoliate below 600 lb D.M. per acre. Utilization was therefore similar across all treatments and intakes a function of grazing intensity.

D.M. production in the low grazing intensity plots once more outproduced by 25% that in the high intensity treatments. Within grazing intensities, grazing duration treatments did not act in a similar manner - the 72 hour treatment being inferior at the low intensity and the 24 hour at the high intensity. The latter was the result of reduced regrowth from plots of this treatment grazed on Day 1 when surface water lay on all plots; over the remaining two days this reduction was less marked. The 6 hour treatment once more showed decreased growth rates.

Control (non-grazed) plots behaved in a similar manner
to those in Experiment I.

Damage to pastures at grazing was reflected in growth
rates over the first ten days of regrowth. After this point,
on most treatments, growth was proportional to that present at
day 10. The main variable affecting initial regrowth appeared
to be changes in tiller populations.

vi. Results of both Experiments were discussed in terms
of pasture response and their short and long term implications
on a whole farm basis.

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A P P E N D I C E S

The following code is used throughout Appendices : —

I   —   Replicate

K   —   Grazing Intensity

L   —   Grazing Duration

M   Day

Appendix 1   :   Meteorological Data.   1969

Information recorded at D.S.I.R., Palmerston North, $\frac{1}{2}$ mile from the experimental area.

(a) Monthly Data

	Mean Maximum Temp.(^{o}F)	Mean Minimum Temp.(^{o}F)	Mean Temp. (^{o}F)	Rainfall (inches)	No.of days	30 year average (inches)
Jan.	70.6	54.6	62.6	3.18	13	3.39
Feb.	69.8	54.1	62.0	2.76	7	2.71
Mar.	68.9	54.0	61.4	1.09	6	2.82
April	62.7	46.8	54.8	2.68	12	3.04
May	58.1	46.1	52.1	3.92	14	3.32
June	52.7	37.4	45.1	2.64	13	3.81
July	51.6	37.4	44.5	1.54	11	3.51
Aug.	55.1	42.3	48.7	2.51	18	3.32
Sept.	61.5	46.4	54.0	1.29	11	2.75
Oct.	59.7	44.8	52.2	1.50	13	3.40

(b) <u>Daily Data over grazing periods</u>

1 June	51.7	36.4	44.1	—
2	50.8	37.3	44.1	—
3	54.3	42.2	48.3	—
4	54.8	31.8	43.3	—
5	54.3	40.0	47.2	—
6	56.2	39.0	47.6	0.08
7	54.8	41.0	47.9	Trace
8	52.0	39.9	46.0	—
9	50.1	40.4	45.3	—
10	53.1	37.5	45.3	—
11	53.2	33.0	43.1	—
12	56.7	40.0	48.4	—
1 August	56.8	44.8	50.8	0.17
2	54.8	49.4	52.1	0.02
3	53.4	34.2	43.8	—
4	51.2	29.8	40.5	—
5	56.2	33.8	45.0	0.23
6	56.2	44.5	50.4	0.05
7	57.5	41.0	49.3	0.58
8	53.9	41.2	47.6	0.08
9	57.1	45.8	52.0	0.47
10	50.8	44.8	47.8	0.04
11	55.1	33.8	44.5	—
12	55.2	44.0	49.6	0.05

Appendix 2 : Schedule of events.

(a) Experiment I

1 April ⎫
2   ⎬ Experimental and pre-treatment areas
3   ⎭ heavily grazed and closed.
⋮

3 May   50 lb N/acre applied to experimental and pre-treatment
         areas.

3 - 31   Plots layed out and fenced.
⋮

4 June   Tiller samples.

5

6   ⎫
7   ⎬ Pre-treatment ⎫
8   ⎭   ⎬ Pre-grazing
                      harvest   ⎫
9   ⎬ Soil moisture ⎫
10 ⎫   ⎭   ⎬ Grazing
11 ⎬ Post-grazing harvest   ⎭
12 ⎭   ⎫ Herbage rejection measurements
        ⎬ Control plots cut
13   ⎭
⋮

19   Tiller samples
⋮

22

23   Soil moisture ⎫ First regrowth harvest.
24   ⎭

25   Ground cover estimate
⋮

4 July   ⎫
5   ⎬ Second regrowth harvest
6   Soil moisture
⋮

14 ⎫
15 ⎬ Third regrowth harvest
16 ⎭
⋮

19   Tiller samples

20

21   Soil moisture
⋮

24 } Fourth regrowth harvest
25 }
26 }
⋮
3 August }
4 } Fifth regrowth harvest   Soil moisture
5 }
6 Soil Bulk densities
⋮
11 Soil moisture
⋮
14 }
15 } Sixth regrowth harvest.
16 }
⋮
19 Tiller counts

(b) Experiment II

1 April } Experimental and pre-treatment areas heavily
2   } grazed and closed.
3   }
⋮
2 June }
3   } Area lightly grazed and closed.
⋮
1 July   50 lb N/acre applied
1 July − 4 August   Plots layed out and fenced
7   } Pre-treatment
8   Tiller counts {
9   }   } Pre-grazing D.M.harvest
10   }   {   } Soil Moisture
11   } grazing   )   }
12   }   } Post-grazing
13   }   }   harvest
⋮
20 }
21 } First regrowth harvest.
22 }
23
24 Tiller counts
25 Soil moisture
⋮
30 }
31 } Second regrowth harvest.
1 Sept. }

```
 9        Soil moisture    ⎫
10                         ⎬    Third regrowth harvest
11                         ⎭
 ⋮
15        Tiller counts
 ⋮
19                    ⎫
20                    ⎬        Fourth regrowth harvest
21                    ⎭
22        Soil moisture
 ⋮
27        Soil bulk density
 ⋮
29                    ⎫
30                    ⎬        Fifth regrowth harvest
 1 Oct.              ⎭
 ⋮
 6        Soil moisture    Tiller counts
```

Appendix 3 : Analysis of variance methods showing the source and df of treatment and error terms (EMS) and the appropriate divisors used in the F. test.

Source	df	F. Ratio Divisor	Source	df	F. Ratio Divisor	Source	df	F. Ratio Divisor
Replicate (R)	2	EMS	Replicate (R)	2	EMS	Replicate (R)	2	EMS
Treatments			Treatments			Treatments		
Grazing intensity (S)	1	EMS	Grazing intensity (S)	1	EMS	Grazing intensity (S)	1	EMS
Grazing duration (T)	2	EMS	Grazing duration (T)	1	EMS	Defoliation technique (T)	1	EMS
S x T	2	EMS	S x T	1	EMS	S x T	1	EMS
R x Treatments			R x Treatments			R x Treatments		
R x S) R x T) 10 (EMS) R x S x T)			R x S) R x T) 6 (EMS) R x S x T)			R x S) R x T) 6 (EMS) R x S x T)		
			Sub-plot					
			Days (D)	2	EMS_2			
			Days x Treatments					
			D x S	2	EMS_2			
			D x T	2	EMS_2			
			D x S x T	2	EMS_2			
			Days x R x Treatments					
			R x S x D) R x T x D) 16 (EMS_2) R x S x T x D) R x D)					
(i)			(ii)			(iii)		

Appendix 4 : Cow Weights - Experiment I and II

(a) Data

I	K	L	lbs Liveweight Expt.I	Expt. II	I	K	L	lbs Liveweight Expt. I	Expt. II
1	1	1	737.3*	758.3	2	2	1	679.3	795.3
1	1	2	760.6	836.6	2	2	2	658.6	886.6
1	1	3	684.0	797.3	2	2	3	754.0	844.0
1	2	1	712.6	789.0	3	1	1	802.0	841.6
1	2	2	751.3	788.0	3	1	2	789.3	803.0
1	2	3	683.3	759.0	3	1	3	794.6	825.0
2	1	1	717.3	825.0	3	2	1	699.3	823.6
2	1	2	655.3	775.6	3	2	2	681.3	790.0
2	1	3	712.3	807.3	3	2	3	718.0	793.3

* Each valve is mean weight at three animals

(b) Analysis of variance

	df	m.s. (Expt I)	m.s. (Expt II)
Grazing intensity	1	5512.40	0.000
Grazing duration	2	142.25	143.5
Interaction	2	712.15	319.5
Replicate	2	3945.05	1876.5*
Replicate x treatment	10	2031.85	414.7
Total	17	2084.10	1044.9

(c) t-test between Replicate means (Experiment II)

Replicate	Mean liveweight
1	788 lb
2	822 lb
3	813 lb

n = 3

EMS (10 df) = 414.7

LSD (0.1) = 21.3

(0.05) = 26.2

(0.01) = 37.3

<u>Appendix 5</u> : D.M. intake and utilization Experiment I

<u>(a) Data</u>

I	K	L	Intake*	Utilization (%)	I	K	L	Intake*	Utilization(%)
1	1	1	13.04	68.1	2	2	1	8.06	80.3
1	1	2	15.35	77.7	2	2	2	8.18	86.9
1	1	3	11.73	63.0	2	2	3	8.07	80.8
1	2	1	8.42	79.7	3	1	1	11.25	67.4
1	2	2	7.58	80.6	3	1	2	12.50	69.9
1	2	3	8.43	78.0	3	1	3	14.05	71.9
2	1	1	10.37	60.2	3	2	1	9.45	79.2
2	1	2	11.21	73.9	3	2	2	8.36	86.8
2	1	3	16.06	73.5	3	2	3	13.02	83.8

* lb D.M./cow/day

<u>(b) Analysis of variance</u>

	df	m.s. Intake	m.s.% utilization
Grazing intensity	1	71.9600**	675.65***
Grazing duration	2	5.2671	71.15*
Interaction	2	1.6199	5.6750
Replicate	2	1.8897	6.0900
Replicate x Treatment	10	3.4897	16.2530
Total	17	7.3183	59.059

<u>(c) t-test within duration means (% utilization)</u>

```
          n    =   6
EMS (10 df)   =  16.253
LSD ( 0.1 )   =   4.22
    (0.05 )   =   5.19
    (0.01 )   =   7.38
```

Appendix 6 : D.M. production – Experiment I

6 – 1 Data

(a) Grazed plots (lb DM/acre)

I	K	L	Pre–	Post	10	20	30	40	50	60
1	1	1	2298	733	845	1020	1043	1293	1483	1681
1	1	2	2372	530	742	843	995	1288	1594	2034
1	1	3	2232	825	737	949	956	1392	1596	1913
1	2	1	2109	429	574	676	842	1138	1323	1651
1	2	2	1880	364	430	527	662	989	1162	1452
1	2	3	2162	476	468	664	699	877	1277	1731
2	1	1	3068	824	860	1067	1093	1428	1526	1776
2	1	2	1819	474	558	683	817	1099	1423	1576
2	1	3	2621	694	755	896	938	1304	1603	2017
2	2	1	2007	395	527	592	753	978	1215	1417
2	2	2	1884	247	354	484	642	857	1010	1336
2	2	3	1996	383	543	734	667	1001	1086	1535
3	1	1	2003	653	792	968	1053	1365	1526	1626
3	1	2	2145	645	662	729	933	1274	1558	1689
3	1	3	2346	660	894	855	1025	1272	1799	2056
3	2	1	2386	497	558	616	731	939	1305	1627
3	2	2	1926	255	422	477	641	866	1052	1256
3	2	3	3108	505	775	625	817	921	1360	1759

(b) Cut plots (lb DM/acre)

I	K	Pre–	Post*	10	20	30	40	50	60
1	1	2011		1000	1212	1232	1232	1365	1727
1	2	2011		598	777	1023	1063	1110	1398
2	1	1957		1099	1364	1409	1502	1407	2417
2	2	1957		635	851	1070	1149	1229	1812
3	1	2245		919	1224	1259	1532	1623	2234
3	2	2245		628	851	1033	1090	1190	1928

* not harvested

6-2 Analysis of Variance

Mean squares $\times$ 10^{-4} at each harvest

	df	Pre-grazing	Post-grazing	10	20	30	40	50	60
Grazing intensity (S)	1	0.8288	45.8161***	46.7883***	64.5504***	41.9497***	70.4865***	72.9411***	61.5681**
Cut v's Grazed (T)	1	6.0320	0.0000	13.7026***	40.9814***	46.2562	8.1541*	1.7609	27.0848*
Grazing duration (D)	2	25.5655*	5.8033***	5.5123**	6.7708***	2.8359*	2.4582	3.6194*	12.4771[+]
S x T	1	0.2763	0.0000	2.2649[+]	2.5238*	0.0082	0.0917	0.7200	1.7298
S x D	2	3.1099	0.493	0.2436	1.1538[+]	0.0672	0.2860	2.1665[+]	3.2402
Replicate	2	14.0459	0.6471	0.3568	0.4388	0.0337	0.0120	2.6194*	1.0806
Replicate x Treatments	14	6.3806	0.4236	0.7150	0.3099	0.4311	0.9877	0.6846	4.3417
Total	23	7.9091	2.8161	3.6952	5.6139	4.3532	4.2571	4.4268	8.0332

6 - 3   t-test information

(a) Grazing duration

Harvest	EMS (14 df)	0.1	LSD (lb DM per acre) 0.05	0.01	0.001
Pre-grazing	63806	256.8	312.8	434.2	
Post-grazing	4236	66.2	80.6	111.0	155.6
Day 10	7150	86.0	104.7	145.3	202.1
Day 20	3099	56.6	68.9	95.7	133.1
Day 30	4311	66.7	81.2	112.7	156.8
Day 40	6846	84.1	102.5	142.2	197.8
Day 60	43417	211.8	258.0	358.1	

n = 6 at all harvests

(b) Grazing duration x Grazing intensity interactions

(i) Day 20   (p < 0.1)

		Intensity (cow days/acre)	
		120	200
	6	1018*	628
Duration	24	752	496
(hours)	72	900	674

* D.M. production (lbs/acre)

EMS = 3099 (14 df)

n = 3

LSD (0.1) = 80.1

(0.05) = 97.5

(0.01) = 135.3

(0.001) = 188.2

(ii) Day 50 (p < 0.1)

		Intensity (cow days/acre)	
		120	200
	6	1512*	1281
Duration	24	1525	1075
(hours)	72	1666	1241

* D.M. production (lbs/acre)

EMS = 6846 (14 df)

n = 3

LSD   (0.1)   =   119.0
      (0.05) =   144.9
      (0.01) =   201.1
     (0.001) =   279.7

(c) Defoliation technique x Grazing intensity interaction
(i) Day 10   (p < 0.1)

	Intensity (cow days/acre)	
	120	200
Cut	1006*	620
Grazed	761	517

* D.M.   production (lbs/acre)
    EMS = 7150 (14 df)
       n = 3 (cut)   n = 9 (grazed)
LSD (0.1)   = 99.2
    (0.05) = 120.8
    (0.01) = 167.7
    (0.001) = 233.2

(ii) Day 20   (p < 0.05)

	Intensity (cow days/acre)	
	120	200
Cut	1267*	826
Grazed	890	599

* D.M. production (lbs/acre)
    EMS = 3099 (14 df)
       n = 3 (cut)   n = 9 (grazed)
LSD (0.1)   = 65.3
    (0.05)   = 79.6
    (0.01)   = 110.4
    (0.001) = 153.5

6 - 4 (a) Analysis of variance of b valves

	df	Mean squares x 10^4
Grazing intensity (S)	1	1.2742 ***
Cut v's grazed (T)	1	1.4365 ***
Grazing duration (D)	2	0.3891 **
S x T	1	0.0147
S x D	2	0.1278+
Replicates	2	0.0065
Replicates x Treatments	14	0.0440

(b) t-test

	EMS (14 df)	n	LSD x 10^3 0.1	0.05	0.01	0.001
Durations	4.4×10^{-6}	6	2.13	2.60	3.61	5.01
Intensity x duration	"	3	3.02	3.67	5.60	7.09
cut x grazed	"	3 (cut)		3.00		5.80
		9 (grazed)				

Appendix 7 : Botanical Analysis Experiment I

Percent Botanical composition of treatment means.

Component	Ryegrass	Timothy	Cocks	Poa	Other grass	Total Sown grass	Unsown	Clover	Dead	Weed
(i) Pre-grazing										
120	41.0	13.3	6.2	11.8	1.8	60.4	14.4	12.7	5.2	7.2
200	39.2	15.0	5.8	11.1	2.2	60.0	13.3	13.5	5.4	7.8
'6 hour'	38.3	15.4	6.3	11.0	1.8	59.9	12.9	14.8	5.2	7.2
'24 hour'	38.8	13.1	5.5	12.4	2.1	57.3	14.6	14.2	6.9	7.0
'72 hour'	43.1	14.0	6.2	10.9	2.1	63.3	14.2	10.3	3.8	8.3
(ii) Post-grazing										
120	26.7	10.9	3.8	7.1	0.3	41.4	7.4	14.4	8.4	28.5
200	23.7	8.6	2.3	5.9	0.1	34.6	6.0	12.9	7.3	39.2
'6 hour'	29.5	10.0	2.2	6.3	0.3	41.6	6.5	11.8	8.6	31.5
'24 hour'	24.2	9.9	3.9	6.1	0.3	38.0	6.4	14.9	7.8	32.8
'72 hour'	21.9	9.4	3.0	7.0	0.01	34.3	7.0	14.3	7.1	37.3
(iii) Regrowth day 10										
120	35.8	10.8	6.9	10.9	0.3	53.5	11.2	13.7	4.9	16.6
200	29.9	9.6	5.9	8.8	0.8	45.0	9.6	17.4	5.9	22.0
'6 hour'	33.8	11.6	7.1	10.5	0.4	52.5	10.9	13.6	7.7	15.0
'24 hour'	33.2	10.5	6.5	8.9	0.9	49.7	9.8	18.3	5.8	16.3
'72 hour'	31.6	8.5	5.6	10.2	0.3	45.7	10.5	14.9	2.7	26.3
(iv) Regrowth day 30										
120	48.2	11.4	7.6	9.8	0.9	68.0	10.7	11.3	3.0	7.9
200	48.1	12.4	8.0	7.6	0.5	68.5	8.1	14.0	3.6	5.8
'6 hour'	49.1	13.0	5.9	9.0	0.5	68.0	9.5	12.9	3.8	5.7
'24 hour'	46.2	11.0	8.4	9.6	0.6	65.5	10.1	13.3	4.3	6.7
'72 hour'	49.1	11.7	9.2	7.4	1.0	70.0	8.5	11.8	1.7	8.0
(v) Regrowth day 50										
120	56.8	5.5	8.0	9.3	0.9	70.2	10.2	10.7	2.8	6.1
200	53.4	6.5	7.2	8.7	0.3	67.3	8.9	15.5	4.1	4.3
'6 hour'	56.0	6.2	7.1	8.5	0.7	69.3	9.2	12.7	3.3	5.6
'24 hour'	55.8	5.4	8.1	8.9	0.7	69.5	9.6	12.7	4.0	4.1
'72 hour'	53.4	6.4	7.6	9.6	0.4	67.4	10.0	13.8	3.0	5.8

(vi) <u>Regrowth day 60</u>

120	47.6	11.3	7.6	12.0	1.6	66.5	13.6	12.4	2.9	4.6
200	52.3	10.2	8.0	10.0	0.6	70.5	10.2	13.5	2.3	3.4
'6 hour'	49.0	11.4	6.7	11.1	1.5	67.0	12.6	13.5	2.7	4.3
'24 hour'	50.9	10.0	7.9	11.5	0.5	68.8	12.1	11.6	3.2	4.3
'72 hour'	50.0	10.9	8.8	9.8	1.3	69.8	11.1	13.7	1.9	3.4

Appendix 8 : Tiller Density — Experiment I

(a) Data (tillers/ft^2)

4 June

I	K	L	Total Grass	Sown Grass	Unsown Grass	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Clover
1	1	1	819	616	203	472	130	14	202	1	279
1	1	2	827	740	87	630	69	41	50	37	295
1	1	3	720	491	229	332	115	44	165	64	398
1	2	1	678	484	229	325	78	46	227	2	378
1	2	2	654	543	110	440	32	71	110	1	146
1	2	3	818	655	163	495	137	23	156	7	440
2	1	1	781	516	265	360	110	46	254	11	426
2	1	2	651	403	248	245	105	53	202	46	387
2	1	3	722	432	290	341	66	25	289	1	376
2	2	1	727	387	340	316	64	7	339	1	435
2	2	2	743	573	170	483	89	1	169	1	467
2	2	3	628	465	163	286	94	85	149	14	307
3	1	1	637	376	261	266	80	30	254	7	529
3	1	2	808	635	173	579	55	1	172	1	460
3	1	3	786	527	259	428	85	14	245	14	419
3	2	1	736	680	56	540	101	39	55	1	197
3	2	2	838	639	199	540	94	5	183	16	437
3	2	3	679	561	118	529	27	5	117	1	261

19 June

I	K	L	Total Grass	Sown Grass	Unsown Grass	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Clover
1	1	1	708	512	196	433	78	1	185	11	293
1	1	2	738	682	56	421	151	110	55	1	250
1	1	3	839	452	387	282	110	60	355	32	261
1	2	1	788	676	111	513	153	11	110	1	282
1	2	2	477	258	219	185	48	25	218	1	295
1	2	3	577	408	169	291	85	32	160	9	325
2	1	1	1021	662	359	369	229	64	350	9	266
2	1	2	583	391	192	169	112	110	190	2	295
2	1	3	641	412	229	213	172	27	218	11	247
2	2	1	521	325	196	227	71	27	195	1	305
2	2	2	690	461	230	314	103	44	229	1	348
2	2	3	495	350	145	96	128	126	144	1	250
3	1	1	815	408	407	256	147	5	382	25	337

3	1	2	658	443	215	259	163	21	204	11	273
3	1	3	727	483	244	353	103	27	243	1	398
3	2	1	443	341	102	192	71	78	101	1	275
3	2	2	510	406	104	234	147	25	103	1	318
3	2	3	482	408	74	259	124	25	73	1	195

19 July

1	1	1	683	401	282	245	71	85	275	7	169
1	1	2	597	444	153	321	41	82	142	11	124
1	1	3	806	499	307	362	64	73	305	2	202
1	2	1	579	327	252	211	89	27	215	37	259
1	2	2	534	322	212	263	50	9	211	1	204
1	2	3	660	369	291	300	48	21	273	18	236
2	1	1	753	431	322	268	87	76	295	27	229
2	1	2	580	337	243	243	41	53	158	85	250
2	1	3	757	455	302	295	103	57	293	9	202
2	2	1	538	271	261	208	55	14	227	34	252
2	2	2	497	323	174	190	115	18	153	21	176
2	2	3	687	419	268	215	78	126	229	39	275
3	1	1	799	509	290	394	78	37	263	27	234
3	1	2	680	392	288	273	110	9	279	9	236
3	1	3	757	455	302	295	103	57	293	9	202
3	2	1	486	405	81	293	78	34	76	5	117
3	2	2	495	314	181	211	89	14	167	14	279
3	2	3	462	343	119	252	66	25	117	2	220

19 August

1	1	1	456	233	223	179	27	27	218	5	135
1	1	2	310	242	68	172	69	1	57	11	142
1	1	3	356	180	176	87	66	27	167	9	115
1	2	1	491	343	148	243	82	18	147	1	124
1	2	2	450	273	175	156	96	23	174	1	121
1	2	3	360	261	99	211	41	9	94	5	115
2	1	1	499	250	250	149	80	21	241	9	105
2	1	2	376	280	96	163	76	41	78	18	73
2	1	3	383	197	186	69	87	41	185	1	89
2	2	1	463	346	117	.231	78	37	112	5	98
2	2	2	369	387	82	156	115	16	73	9	133
2	2	3	499	250	249	149	80	21	240	9	105

3	1	1	437	203	234	98	71	24	211	23	121
3	1	2	550	266	284	151	92	23	263	21	87
3	1	3	449	316	133	206	64	46	126	7	80
3	2	1	287	211	76	147	37	27	32	44	66
3	2	2	407	244	163	169	64	11	147	16	87
3	2	3	331	243	88	179	57	7	87	1	76

(b) Analysis of Variance

mean squares x 10^{-2}

4 June	df	Total Grass	Sown Species	Unsown Grass	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Clover
Replicate	2	34.595	275.415	104.764	333.087	6.291	10.177	110.249	2.162	99.211
Grazing Intensity	1	34.722	35.001	121.160	50.332	5.445	0.109	59.769	10.580[+]	139.444
Grazing duration	2	13.694	108.740	57.594	189.028	6.134	0.242	82.597	3.424	1.287
Interaction	2	1.327	28.949	42.098	17.044	2.435	0.969	41.861	1.235	7.666
Rep x treatment	10	71.220	105.489	42.736	119.559	11.777	7.898	45.414	3.200	137.369
Total	17	49.774	112.712	56.319	136.720	8.996	5.992	57.843	3.307	101.733
19 June										
Replicate	2	103.582	114.254	24.294	249.327	15.722	21.037	29.994	0.375	4.264
Grazing Intensity	1	1695.559**	366.301*	485.681*	109.520	62.347	0.569	400.445*	4.109*	0.405
Grazing duration	2	196.347	73.720	54.161	116.729	0.377	9.991	44.309	0.682	4.937
Interaction	2	106.282	195.52	204.404[+]	3.686	5.467	23.454	186.480[+]	0.424	33.215
Rep x Treatment	10	158.691	42.624	69.589	100.990	23.123	13.339	59.951	0.681	27.073
Total	17	240.876	142.028	102.782	109.347	19.806	14.290	89.501	0.817	20.939
19 July										
Replicate	2	14.527	13.476	43.474	47.152	11.501	12.521	22.509	11.562	15.042
Grazing Intensity	1	1207.042**	377.207**	234.722*	169.894*	0.500	32.267[+]	224.014*	0.125	16.056

Source	df									
Grazing duration	2	235.617*	69.469[+]	50.171	19.847	0.116	12.616	67.601	2.007	2.954
Interaction	2	38.236	5.817	14.288	0.202	8.187	5.502	34.254	5.360	7.007
Rep x treatment	10	46.741	21.894	40.498	20.637	5.215	8.998	36.198	3.258	29.233
Total	17	132.424	45.509	50.327	30.039	5.427	10.795	49.101	4.151	21.082

19 August

Source	df									
Replicate	2	12.607	6.837	4.502	7.737	9.834	2.187	2.565	2.912	23.562
Grazing intensity	1	14.045	47.045	114.005	78.827[+]	0.180	4.702[+]	107.555	0.094	0.269
Grazing duration	2	28.145	11.217	13.905	8.909	9.127	1.074	12.182	1.412	24.349
Interaction	2	12.066	17.955	58.182	20.402	2.682	2.777	68.644	0.577	56.940
Rep x treatment	10	78.690	24.499	52.556	20.621	3.583	1.012	54.852	0.957	2.707
Total	17	53.329	21.415	46.632	20.890	4.664	1.582	48.404	1.145	53.365

(c) t-tests

19 June

    (i) Unsown species - grazing intensity x grazing duration interaction (p < 0.1)

	120 cow days/acre	200 cow days/acre
Grazing 6	321*	136
duration 24	154	184
72	287	129

    * tillers/ft^2

        n = 3
EMS(10 df) = 6958.9
LSD(0.1) = 123.4
  (0.05) = 151.7
  (0.01) = 215.8

    (ii) Poa species - grazing intensity x grazing duration interaction (p < 0.1)

	120 cow days/acre	200 cow days/acre
Grazing 6	306*	135
duration 24	150	183
72	272	126

    * tillers/ft^2

        n = 3
EMS(10 df) = 5995.0
LSD(0.1) = 114.6
  (0.05) = 140.9
  (0.01) = 200.3

19 July   Between grazing duration means

    (i) Total grasses (p < 0.05)

        n = 6
EMS(10 df) = 4674.1
LSD(0.1) = 71.5
  (0.05) = 87.9
  (0.01) = 125.1

(ii) <u>Sown grass species</u> ($p < 0.1$)

$$n = 6$$

EMS (10 df) = 2189.0

LSD (0.1) = 48.9

(0.05) = 60.2

(0.01) = 85.6

Appendix 9 : Ground cover - Experiment I

(a) Data (% bare ground)

I	K	L	Bare ground	I	K	L	Bare ground
1	1	1	12.0	2	2	1	22.0
1	1	2	15.0	2	2	2	27.0
1	1	3	19.0	2	2	3	29.0
1	2	1	21.0	1	1	1	12.0
1	2	2	26.0	1	1	2	17.0
1	2	3	30.0	1	1	3	15.0
2	1	1	10.0	1	2	1	32.0
2	1	2	14.0	1	2	2	29.0
2	1	3	23.0	1	2	3	25.0

(b) Analysis of variance

	df	Means square	f
Grazing intensity	1	600.89	47.07***
Grazing duration	2	43.17	3.38[+]
Interaction	2	8.39	0.66
Replicate	2	2.17	0.17
Replicate x Treatment	10	12.77	
Total	17	49.18	

(c) t-test between duration means

$$n = 6$$

EMS (10 df)= 12.77

LSD (0.1) = 2.44

(0.05) = 4.60

(0.01) = 6.54

Appendix 10 : Evenness of grazing - Experiment I

(a) Data (lbs D.M. per acre)

I	K	L	Rejection		I	K	L	Rejection
1	1	1	83.2		2	2	1	45.4
1	1	2	63.6		2	2	2	20.3
1	1	3	44.0		2	2	3	10.9
1	2	1	7.6		3	1	1	64.5
1	2	2	2.0		3	1	2	39.0
1	2	3	31.8		3	1	3	68.0
2	1	1	98.9		3	2	1	41.8
2	1	2	32.3		3	2	2	22.0
2	1	3	44.8		3	2	3	38.9

(b) Analysis of variance

	df	Mean square	F
Grazing intensity	1	5603.88	19.32**
Grazing duration	2	1122.85	3.87+
Interaction	2	273.62	0.9
Replicate	2	73.52	0.25
Replicate x reatment	10	290.12	
Total	17	673.24	

(c) t-test between grazing duration means

Treatment	lb DM/acre rejection
6 hour	56.9
24 hour	29.9
72 hour	39.7

$$n = 6$$
$$\text{EMS (10 df)} = 290.12$$
$$\text{LSD (0.1)} = 17.8$$
$$(0.05) = 21.9$$
$$(0.01) = 31.2$$

Appendix 11 : Soil Bulk Density – Experiment I

(a) Data

I	K	L	0 – 3cm	3 – 6cm	6 – 9cm	0 – 9cm
1	1	1	0.809*	1.001	1.099	0.970
1	1	2	0.762	0.930	1.035	0.909
1	1	3	0.865	1.014	1.069	0.983
1	2	1	0.817	0.954	1.065	0.945
1	2	2	0.832	1.000	1.079	0.970
1	2	3	0.830	1.001	1.087	0.973
2	1	1	0.789	0.970	1.093	0.951
2	1	2	0.753	0.997	1.132	0.961
2	1	3	0.749	0.918	1.056	0.908
2	2	1	0.758	0.967	1.114	0.949
2	2	2	0.779	0.999	1.097	0.958
2	2	3	0.815	1.000	1.065	0.960
3	1	1	0.820	0.950	1.057	0.942
3	1	2	0.842	0.934	1.040	0.939
3	1	3	0.782	0.943	1.028	0.918
3	2	1	0.886	0.931	1.031	0.949
3	2	2	0.833	0.985	1.066	0.961
3	2	3	0.841	0.919	0.968	0.909

* gm/cc

1			0.819	0.983	1.072	0.958
2			0.774	0.975	1.093	0.948
3			0.834	0.944	1.032	0.936

(b) Analysis of variance

Source	df	Mean squares x 10^2			
		0–3	3–6	6–9	0–9
Grazing intensity	1	2.688	0.054	0.007	0.480
Grazing duration	2	0.351	0.022	0.182	0.147
Interaction	2	0.116	0.155	0.028	0.418
Replicates	2	5.895*	0.263	0.581*	0.726
Replicate x Treatments	10	1.111	0.090	0.082	0.602
Total	17	1.560	0.108	0.142	0.534

(c) t-test (between Reps)

Layer	EMS	n	0.05	0.01	0.001
0–3 cm	1.111×10^{-2}	6	0.0429	0.0610	0.0883
6–9 cm	0.082×10^{-2}	6	0.0368	0.0523	0.0757

Percent Botanical composition of treatment means.

Component	Ryegrass	Timothy	Cocks	Poa	Other Grass	Total Sown Grass	Unsown Grass	Clover	Dead	Weed
(i) Regrowth day 10										
grazed	32.7	10.2	6.3	9.9	0.5	49.2	10.4	15.4	5.3	19.7
cut	32.2	10.6	5.6	19.9	1.5	49.4	21.4	10.4	7.0	11.7
120	34.6	11.4	6.8	17.1	1.0	52.9	18.0	11.6	5.0	12.4
200	30.3	10.4	5.0	12.7	1.0	45.7	13.8	14.2	7.3	19.0
(ii) Regrowth day 30										
grazed	48.2	12.0	7.7	8.6	0.7	67.9	9.3	12.7	3.2	6.8
cut	43.1	11.4	5.0	19.3	1.6	59.5	20.9	8.2	5.4	6.0
120	45.8	11.0	5.9	15.1	1.4	62.7	16.6	9.1	4.4	7.2
200	45.6	12.3	6.8	12.7	0.9	64.7	13.6	11.8	4.3	5.6
(iii) Regrowth day 50										
grazed	55.1	6.0	7.6	8.9	0.6	68.7	9.5	13.1	3.4	5.2
cut	45.6	5.6	6.4	16.1	1.5	57.6	17.7	11.7	6.2	6.8
120	50.5	5.3	6.6	13.7	1.2	62.3	14.9	11.2	4.6	7.0
200	50.2	6.3	7.4	11.4	1.0	64.0	12.3	13.6	5.0	5.0
(iv) Regrowth day 60										
grazed	50.0	10.8	7.8	10.7	1.1	68.7	11.8	12.9	2.6	4.0
cut	46.2	9.5	5.6	18.3	1.4	61.3	19.7	10.1	4.5	4.3
120	46.0	10.0	5.6	16.9	1.6	61.6	18.4	10.4	4.8	4.8
200	50.3	10.3	7.8	12.2	0.9	68.4	13.1	12.6	2.3	3.5

Appendix 13 : Tiller Density — Experiment I

(a) Data (tillers 1ft^2)

I	K	Total grass	Sown grass	Unsown grass	Ryegrass	Timothy	Cocksfoot	Poa	Other grass	Clover
19 June – grazed										
1	1	762	549	213	379	113	57	198	15	268
1	2	614	447	166	330	95	23	163	4	301
2	1	748	488	260	250	171	67	253	7	269
2	2	569	379	190	212	101	66	189	1	301
3	1	733	445	289	289	138	18	276	12	336
3	2	478	385	93	228	114	43	92	1	263
19 June – cut										
1	1	945	440	505	298	119	23	496	9	468
1	2	956	478	479	336	87	53	398	81	338
2	1	1011	345	666	230	78	37	537	129	386
2	2	842	511	331	381	107	23	292	38	373
3	1	854	514	340	289	179	46	280	60	280
3	2	723	368	356	259	93	16	344	11	324
19 July – grazed										
1	1	695	448	247	309	59	80	241	1	165
1	2	591	339	252	258	66	19	233	19	233
2	1	697	408	289	269	77	62	249	40	227
2	2	574	340	234	204	83	53	203	31	234
3	1	745	452	293	321	97	34	278	14	224
3	2	481	354	127	252	78	24	120	7	205
19 July – cut										
1	1	886	409	482	312	37	60	445	37	220
1	2	818	347	471	233	103	11	427	44	263
2	1	1016	434	582	360	32	42	550	32	104
2	2	659	288	371	188	73	27	346	25	226
3	1	1144	460	684	409	28	23	656	28	183
3	2	821	346	475	231	78	37	465	10	173

19 August – grazed

1	1	374	218	156	146	54	18	147	8	131
1	2	434	292	141	203	73	17	138	2	120
2	1	419	242	177	127	81	34	168	9	89
2	2	444	294	149	179	91	25	142	8	112
3	1	479	262	217	152	76	34	200	17	96
3	2	342	233	109	165	53	15	89	20	76

19 August – cut

1	1	684	303	381	110	161	32	372	9	110
1	2	667	332	335	145	176	11	321	14	107
2	1	520	299	221	202	92	5	216	5	60
2	2	519	252	268	100	138	14	240	27	40
3	1	597	303	294	193	92	18	271	23	115
3	2	537	318	219	188	93	37	200	19	112

(b) <u>Analysis of variance</u>

mean squares $\times\ 10^{-2}$

	df	Total grass	Sown grass	Unsown grass	Ryegrass	Timothy	Cocksfoot	Poa	Other grass	Clover
19 June										
Grazing intensity	1	632.201**	37.808	360.803+	0.101	33.668	0.480	263.203+	7.680	9.541
Cut v's grazed	1	1696.941***	1.140	1790.962**	9.188	3.968	4.813	1152.480**	69.120+	154.801+
Interaction	1	71.539	90.201	0.854	78.540	0.441	0.013	0.013	1.333	6.901
Replicate	2	165.206*	32.253	93.518	62.604	7.683	3.066	61.361	5.361	19.824
Rep x treatment	6	27.596	45.688	91.728	24.615	9.527	4.491	66.217	14.467	31.797
Total	11	263.334	42.526	262.729	32.794	10.055	3.490	175.974	15.999	36.515
19 July										
Grazing intensity	1	1279.267**	297.007***	348.841+	314.163***	18.008*	14.083*	325.521*	0.241	33.394
Cut v's grazed	1	2030.601**	2.708	2195.107***	12.000	9.188+	4.320	2041.021***	3.308	10.830
Interaction	1	55.039	1.841	38.521	49.613*	23.241*	0.750	33.667	0.301	7.363
Replicate	2	42.651	12.606	11.381	23.061	0.280	3.023	24.656	2.931	6.826
Rep x treatment	6	84.244	3.977	59.170	7.670	2.441	3.621	53.882	1.840	21.488
Total	11	359.606	31.875	269.114	42.554	5.968	4.266	252.074	1.886	17.831

19 August

	df									
Grazing intensity	1	14.083	7.363	42.188	2.083	3.853	0.403	49.614	0.301	0.963
Cut v's grazed	1	887.519**	58.963+	492.801**	0.963	87.480*	0.563	451.414**	0.908	5.333
Interaction	1	0.564	8.333	4.941	31.363	2.613	1.080	1.919	0.608	0.270
Replicate	2	46.031	2.103	29.190	7.063	14.203	0.563	38.543	1.363+	17.606
Rep x treatment	6	48.623	11.023	27.656	14.473	8.202	1.472	25.965	0.348	6.121
Total	11	116.906	13.181	69.477	12.307	15.597	1.092	66.893	0.603	7.137

(c) t-tests   Grazing intensity x defoliation treatment interaction

   (i) Ryegrass (19 July) $p < 0.05$.

		120 cow days/acre	200 cow days/acre
Defoliation	grazed	299.7*	238.0
Treatment	cut	360.3	217.3

* Tillers per ft^2

$$
\begin{aligned}
n &= 3 \\
\text{EMS (6df)} &= 769.97 \\
\text{LSD } (0.1) &= 44.0 \\
(0.5) &= 55.4 \\
(0.01) &= 84.0 \\
(0.001) &= 135.03
\end{aligned}
$$

(ii) Timothy (19 July) $p < 0.05$

		120 cow days/acre	200 cow days/acre
Defoliation	grazed	77.7*	74.3
Treatment	cut	32.3	84.7

* Tillers per ft^2

$$
\begin{aligned}
n &= 3 \\
\text{EMS (6df)} &= 244.1 \\
\text{LSD } (0.1) &= 24.8 \\
(0.05) &= 31.2 \\
(0.01) &= 47.3
\end{aligned}
$$

Appendix 14 : Ground cover – Experiment I

(a) Data

Grazed			Cut		
I	K	% Bare ground	I	K	% Bare ground
1	1	15.0	1	1	8.0
1	2	26.0	1	2	11.0
2	1	16.0	2	1	8.0
2	2	26.0	2	2	12.0
3	1	15.0	3	1	4.0
3	2	29.0	3	2	15.0

(b) Analysis of variance

	df	m.s.	F
Grazing intensity	1	234.08	56.56 ***
Cut v's Grazed	1	396.75	95.86 ***
Interaction	1	24.08	5.82 +
Replicates	2	0.58	0.14
Replicates x Treatments	6	4.14	
Total	11	61.90	

(c) t-test within grazing intensity x defoliation treatments

$$n = 3$$

EMS (6 df) = 4.14

LSD (0.1) = 5.36

(0.05) = 6.75

(0.01) = 10.23

Appendix 15 : Soil Moisture — Experiment I

(a) Data (Moisture %)

Grazed

I	K	23 June	6 July	21 July	4 August	11 August
1	1	36.9	37.6	35.8	40.0	40.7
1	2	36.4	35.8	37.0	40.6	40.3
2	1	36.9	37.7	35.8	39.6	40.6
2	2	36.1	37.9	36.6	40.0	40.7
3	1	38.5	39.8	39.2	42.7	43.1
3	2	36.7	38.3	37.1	41.4	43.0

Cut

I	K	23 June	6 July	21 July	4 August	11 August
1	1	38.6	40.6	40.2	42.9	44.0
1	2	38.4	38.2	39.1	41.6	42.1
2	1	40.8	37.4	38.5	38.9	39.0
2	2	38.8	38.7	39.1	42.1	42.2
3	1	40.3	36.8	40.6	39.7	41.2
3	2	38.5	38.7	36.9	40.9	41.5

(c) Analysis of variance

	df	23 June	6 July	21 July	4 August	11 August
				Mean squares		
Grazing intensity	1	4.2010*	0.4410	1.5410	0.6530	0.1190
Grazed v's cut	1	16.1010**	0.9080	13.8680*	0.2690	0.2130
Interaction	1	0.0670	1.2660	1.400	0.9640	0.3340
Replicate	2	0.8725	0.2425	0.9060	1.5505	2.6560
Rep x Treatment	6	0.4814	2.4538	1.9582	2.2100	2.6315
Total	11	2.2730	1.6203	2.7609	1.6588	1.9788

Appendix 16 : Bulk Density – Experiment I

(a) Data (gm/cc)

(i) Grazed

I	0 – 3 cm	3 – 6 cm	6 – 9 cm	0 – 9 cm
1	0.819	0.983	1.072	0.953
2	0.774	0.975	1.093	0.948
3	0.834	0.944	1.032	0.936

(ii) Control

1	0.842	0.961	1.043	0.949
2	0.810	0.931	1.035	0.942
3	0.772	0.615	1.009	0.799

(b) Analysis of variance

	df	0–3	3–6	6–9	0–9
Grazed v's control	1	0.000	1.995	0.201^{+}	0.385
Replicate	2	0.078	2.543	0.110	0.449
Rep x Treatment	2	0.141	1.721	0.017	0.279
Total	5	0.088	2.104	0.091	0.368

Mean squares x 10^{2}

Appendix 17 : D.M. intake and utilization – Experiment II

(a) Data

I	K	L	Intake*	Utilization(%)	I	K	L	Intake*	Utilization(%)
1	1	1	9.66	67.9	2	2	1	3.48	55.0
1	1	2	10.08	65.5	2	2	2	3.75	54.9
1	1	3	7.59	61.0	2	2	3	4.63	57.7
1	2	1	4.83	65.0	3	1	1	6.80	57.1
1	2	2	5.68	65.6	3	1	2	10.10	69.7
1	2	3	4.42	56.0	3	1	3	9.47	69.5
2	1	1	7.32	57.5	3	2	1	3.01	47.9
2	1	2	8.12	60.8	3	2	2	6.76	77.2
2	1	3	7.68	64.2	3	2	3	5.51	68.3

* lb D.M./cow/day

(b) Analysis of variance

	df	m.s. Intake	% utilization
Grazing intensity	1	67.2027***	36.7500
Grazing duration	2	3.6632+	80.2180
Interaction	2	0.2540	13.3690
Replicate	2	2.7052	72.4855
Replicate x Treatment	10	1.1156	49.1236
Total	17	5.3884	50.6181

(c) t-test between duration means (Intake)

$$n = 6$$
$$EMS = 1.1156 \text{ (10 df)}$$
$$LSD\ (0.1) = 1.01$$
$$(0.05) = 1.36$$
$$(0.01) = 1.93$$

Appendix 18 : D.M. Production - Experiment II

18.1 Data

(a) Grazed plots (lb D.M./acre)

I	K	L	Pre-	Post-	10	20	30	40	50
1	1	1	1708	549	727	1186	1524	2232	3278
1	1	2	1847	637	585	1025	1583	2199	3177
1	1	3	1493	582	506	861	1351	2097	2398
1	2	1	1487	521	496	835	1127	1698	2402
1	2	2	1720	591	427	769	1028	1450	2381
1	2	3	1577	694	476	898	1396	1925	2645
2	1	1	1528	649	676	1070	1569	2078	2878
2	1	2	1604	629	664	1151	1585	2167	3282
2	1	3	1436	514	522	888	1279	1830	2896
2	2	1	1264	570	569	806	1152	1692	2396
2	2	2	1366	616	395	720	1013	1614	2126
2	2	3	1604	679	567	909	1344	2000	2839
3	1	1	1427	611	645	1075	1500	2017	3096
3	1	1	1738	526	575	954	1441	2271	3514
3	1	3	1635	490	468	855	1534	2366	3357
3	2	1	1258	656	618	987	1432	1962	2672
3	2	2	1751	399	302	510	840	1529	2444
3	2	3	1614	512	435	815	1423	1730	2553

(b) Cut plots (lb D.M./acre)

I	L	Pre-	Post-	10	20	30	40	50
1	1	1748	747	1093	1490	1773	2262	2900
1	2	1748	519	825	1104	1464	2105	3196
2	1	1405	820	1193	1379	1825	1986	3126
2	2	1405	490	907	1086	1609	1812	2806
3	1	1939	659	1045	1337	1933	2796	3884
3	2	1939	408	728	1029	1626	2394	3203

(c) Mean D.M. production per replicate (lb D.M./acre)

I	Pre-	Post-	10	20	30	40	50
1	1966	605	522	1021	1531	1996	2798
2	1452	621	555	1001	1422	1897	2794
3	1663	533	491	946	1466	2133	3090

18.2 Analysis of variance

Mean squares $\times\ 10^{-4}$ at each harvest

	df	Pre-grazing	Post grazing	10	20	30	40	50
Grazing intensity (s)	1	2.5026	2.3940*	15.9088***	32.7367***	49.3927***	80.3004***	156.2130***
Cut v's Grazed (T)	1	8.6459+	0.3528	82.7756***	49.3521***	59.9330***	37.6712**	68.2696**
Grazing Duration (D)	2	7.6394	0.1042	3.2967***	3.4322*	7.5761+	2.1930	0.2713
S x T	1	0.8342	8.5285**	3.2513**	1.8209+	0.0184	2.9525	15.1525
S x D	2	3.3731	1.0581	1.9382**	5.6201**	12.4289***	8.9810	24.1675+
Replicate	2	12.0794*	1.7704*	1.4339*	1.2340	0.7808	11.2144+	23.2091+
Replicate x Treatment	14	1.9195	0.4249	0.2400	0.5861	1.0473	3.9853	6.5655
Total	23	3.6973	1.0039	5.1580	4.8995	6.8696	9.6302	18.5586

18.3 t-test information

(a) grazing duration

Harvest	EMS (14 df)	L.S.D. (lb D.M. per acre)			
		0.1	0.05	0.01	0.001
Pre-grazing	19195	140.8	171.5	238.0	
Day 10	2400	49.8	60.7	84.2	117.1
Day 20	5861	77.9	94.8	131.6	183.0
Day 30	10473	99.0	120.5	167.3	

n = 6 at all harvests

(b) Replicates

Harvest	EMS	0.1	0.05	0.01	0.001
Pre-grazing	19195	122.0	148.6	206.2	286.1
Post-grazing	4249	57.4	69.9	97.0	
Day 10	2400	43.1	52.6	72.9	
Day 40	39853	175.7	214.1	297.1	
Day 50	65655	225.6	274.8	381.4	

n = 8 at all harvests

(c) Grazing duration x Grazing intensity interactions

(i) Day 10   ($p < 0.01$)

		Intensity (cow days per acre)	
		120	200
Duration	6	683*	561
(hours)	24	608	375
	72	499	493

*D.M. production (lbs/acre)

n = 3

EMS = 2400 (14 df)

LSD (0.1) = 70.4

(0.05) = 85.8

(0.01) = 119.1

(0.001)= 165.6

(ii) <u>Day 20</u> (p $<$ 0.01)

		Intensity (cow days/acre)	
		120	200
Duration	6	1110*	876
(hours)	24	1043	666
	72	868	874

*<u>D.M. Production</u> (lbs/acre)

n = 3
EMS = 5861 (14 df)
LSD(0.1)= 110.1
　　(0.05)= 134.1
　　(0.01)= 186.1
　　(0.001)= 258.8

(iii) <u>Day 30</u> (p $<$ 0.001)

		Intensity (cow days/acre)	
		120	200
Duration	6	1531*	1237
(hours)	24	1536	960
	72	1388	1388

*<u>D.M. production</u> (lbs/acre)

n = 3
EMS = 10473 (14 df)
LSD(0.1) = 139.9
　(0.05) = 170.5
　(0.01) = 236.6
　(0.001) = 329.0

(iv) <u>Day 50</u> (p $<$ 0.1)

		Intensity (cow days/acre)	
		120	200
Duration	6	3084*	2490
(hours)	24	3324	2317
	72	2884	2679

*<u>D.M. production</u> (lbs/acre)

EMS = 65655 (14 df)　　n = 3
LSD(0.1) = 365.6
　(0.05) = 445.3
　(0.01) = 618.1
　(0.001)= 859.5

(d) <u>Defoliation technique x Grazing intensity interaction</u>

(i) <u>Post-grazing</u> (p < 0.01)

	Intensity (cow days per acre)	
	120	200
Cut	742*	472
Grazed	576	582

* D.M. production (lbs/acre)

n = 3 (cut)   n = 9 (grazed)
EMS = 4249 (14 df)
LSD(0.1) = 76.5
(0.05) = 93.2
(0.01) = 129.3
(0.001) = 179.8

(ii) Day 10 (p < 0.01)

	Intensity (cow days per acre)	
	120	200
Cut	1110*	820
Grazed	597	476

* D.M. production (lbs/acre)

n = 3 (cut)   n = 9 (grazed)
EMS = 2400 (14 df)
LSD(0.1) = 57.5
(0.05) = 70.1
(0.01) = 97.2
(0.001) = 135.2

(iii) Day 20 (p < 0.1)

	Intensity (cow days per acre)	
	120	200
Cut	1402*	1073
Grazed	1007	806

* D.M. production (lbs/acre)

n = 3 (cut)   n = 9 (grazed)
EMS = 5861 (14 df)
LSD(0.1) = 89.8
(0.05) = 109.4
(0.01) = 151.9
(0.001) = 211.2

(a) Analysis of variance of b values

	df	Mean Squares x 104
Grazing intensity (S)	1	0.2882[+]
Cut v's grazed (T)	1	5.5722 ***
Grazing duration (D)	2	0.8120 **
S x T	1	0.3486 [+]
S x D	2	0.1443
Replicates	2	0.9116 **
Replicates x Treatments	14	0.0807

(b) t-tests

			L.S.D. x 10³			
	EMS (14df)	n	0.1	0.05	0.01	0.001
Durations	8.07×10^{-6}	6	2.89	3.52	4.88	6.79
Intensity x Durations	"	3	4.09	4.98	7.91	9.61
Intensity x Defoliation method	"(3 cut)			4.10		7.80
	(9 grazed)					

Appendix 19: Botanical Analysis — Experiment II

Percent Botanical composition of treatment means.

(i) Pre-grazing

	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Total Sown Grass	Unsown Grass	Clover	Dead	Weed
120	44.7	8.5	15.1	6.4	3.5	68.2	9.9	13.5	2.2	6.0
200	44.8	9.5	15.1	6.9	3.8	69.4	10.7	11.4	2.2	6.3
'6 hour'	44.2	9.9	15.1	7.8	2.9	69.3	10.8	11.4	2.7	5.9
'24 hour'	49.0	8.5	14.1	6.0	3.0	71.6	9.0	11.2	1.6	6.5
'72 hour'	41.0	8.6	15.9	6.1	5.0	65.5	11.1	14.78	2.4	6.1

(ii) Harvest Day 10

	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Total Sown Grass	Unsown Grass	Clover	Dead	Weed
120	41.4	11.2	13.2	4.8	2.7	65.8	7.5	12.1	3.2	11.5
200	34.6	12.1	14.2	5.2	3.1	60.7	8.3	13.5	3.3	14.2
'6 hour'	37.7	11.2	14.8	5.2	2.9	63.6	8.1	12.1	3.6	12.5
'24 hour'	42.9	11.9	13.9	3.8	2.3	68.3	6.1	10.4	1.9	13.4
'72 hour'	33.5	11.9	12.4	5.9	3.5	57.8	9.5	15.9	4.1	12.7

(iii) Harvest Day 30

	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Total Sown Grass	Unsown Grass	Clover	Dead	Weed
120	45.2	11.3	11.5	5.9	1.9	68.0	7.8	17.1	3.8	3.1
200	39.8	15.4	9.2	8.2	2.3	64.4	10.5	18.0	4.2	2.9
'6 hour'	39.6	13.7	9.1	8.1	2.8	62.4	11.0	18.4	5.1	3.1
'24 hour'	47.4	13.4	11.3	5.6	1.4	72.1	7.1	14.5	3.5	2.8
'72 hour'	40.5	12.9	10.7	7.2	2.2	64.2	9.4	19.9	3.4	3.1

(iv) Harvest Day 50

	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass	Total Sown Grass	Unsown Grass	Clover	Dead	Weed
120	47.0	12.4	10.6	6.6	3.9	69.9	10.2	12.7	3.2	4.0
200	42.6	12.5	9.9	7.2	4.4	65.0	11.7	14.4	5.0	3.9
'6 hour'	41.6	11.2	9.3	8.0	5.1	62.1	12.7	16.0	4.8	4.4
'24 hour'	52.2	10.8	10.1	5.3	2.6	73.1	8.1	11.5	3.5	3.8
'72 hour'	40.6	15.3	11.3	7.4	4.6	67.2	12.0	13.2	4.0	3.5

Appendix 20 : Experiment II – Tiller Density

(a) Data (tillers/ft^2)

I	K	L	Total grass	Sown grass	Unsown grass	Ryegrass	Timothy	Cocksfoot	Poa	Other grass	Clover
8 August											
1	1	1	546	396	150	270	98	29	106	44	155
1	1	2	478	385	92	247	93	44	53	39	127
1	1	3	561	316	245	144	133	39	94	151	119
1	2	1	599	420	179	236	115	69	122	57	151
1	2	2	578	380	198	229	80	72	112	86	118
1	2	3	485	368	117	213	121	34	62	55	185
2	1	1	530	375	154	203	86	86	99	56	147
2	1	2	563	337	226	178	120	39	116	110	176
2	1	3	358	248	110	78	115	55	25	85	76
2	2	1	642	367	275	186	155	25	105	170	139
2	2	2	479	284	195	121	122	40	76	119	165
2	2	3	636	366	270	204	128	34	172	98	220
3	1	1	434	330	104	186	83	61	51	53	155
3	1	2	493	423	70	285	90	48	39	31	153
3	1	3	605	575	30	476	69	30	25	5	218
3	2	1	589	359	230	153	144	62	113	117	166
3	2	2	490	385	105	191	105	90	78	27	179
3	2	3	627	492	135	337	105	50	121	14	179
24 August											
1	1	1	416	335	81	201	87	47	57	25	105
1	1	2	280	236	44	146	72	18	31	13	65
1	1	3	481	302	179	174	73	55	103	76	119
1	2	1	338	277	61	126	130	21	51	10	101
1	2	2	296	218	78	117	63	37	45	33	56
1	2	3	239	137	101	39	78	21	57	44	85
2	1	1	464	330	133	173	108	50	101	33	82
2	1	2	483	353	134	172	129	49	98	36	115
2	1	3	475	363	112	76	202	85	87	25	94
2	2	1	567	361	206	147	110	105	115	91	130
2	2	2	312	217	95	81	105	31	85	11	118
2	2	3	330	222	108	89	78	55	94	14	153

3	1	1	465	367	98	162	141	64	61	38	140
3	1	2	426	366	61	179	111	75	49	12	79
3	1	3	471	417	54	291	71	55	53	1	137
3	2	1	489	298	192	124	108	65	150	42	172
3	2	2	119	106	13	36	47	24	6	7	53
3	3	3	552	430	122	231	117	82	115	7	137

15 September

1	1	1	374	273	101	169	67	37	88	13	82
1	1	2	324	247	77	146	63	38	74	3	98
1	1	3	457	324	133	218	101	5	87	46	158
1	2	1	344	275	69	183	81	11	66	3	94
1	2	2	263	193	70	121	46	26	52	1 8	50
1	2	3	358	298	60	220	55	23	46	14	126
2	1	1	372	269	103	166	52	51	87	16	72
2	1	2	323	240	82	157	59	24	69	13	103
2	1	3	392	229	163	98	94	37	117	46	140
2	2	1	400	224	176	92	80	52	124	53	120
2	2	2	268	156	113	79	61	16	79	34	79
2	2	3	286	169	117	87	34	48	87	30	179
3	1	1	329	233	85	128	70	35	61	24	92
3	1	2	364	271	93	185	58	28	79	14	92
3	1	3	305	282	23	199	46	37	16	7	126
3	2	1	459	298	162	148	109	41	119	42	130
3	2	2	216	195	22	123	41	31	16	5	59
3	2	3	375	286	89	156	103	27	82	7	185

6 October

1	1	1	210	144	75	85	30	20	65	10	76
1	1	2	257	214	42	149	50	15	41	1	61
1	1	3	231	121	110	57	41	23	66	44	78
1	2	1	271	217	54	134	71	13	44	9	85
1	2	2	224	118	106	80	28	10	84	23	58
1	2	3	204	112	92	89	9	14	71	21	105
2	1	1	290	201	89	133	24	45	72	17	40
2	1	2	221	142	79	89	28	24	65	14	63
2	1	3	367	238	129	128	23	87	85	44	119
2	2	1	361	255	106	141	93	21	54	51	86
2	2	2	223	142	81	69	45	28	66	15	67

2	2	3	336	144	192	80	50	14	103	89	119
3	1	1	342	250	92	145	64	41	52	40	88
3	1	2	262	191	71	135	39	17	62	9	58
3	1	3	195	130	65	103	18	9	64	1	44
3	2	1	315	171	143	101	49	21	110	33	89
3	2	2	204	173	32	106	43	24	28	4	71
3	2	3	283	186	97	101	55	30	92	5	89

(b) Analysis of Variance

mean squares x 10^{-4}

Source	df	Total grass	Sown grass	Unsown grass	Ryegrass	Timothy	Cocksfoot	Other grass	Poa	Clover
8 August										
Rep.	2	0.0069	1.4359	1.2927[+]	1.8129	0.0729	0.0190	0.6376[+]	0.1233	0.1633
Grazing intensity	1	1.7236	0.0072	1.5196[+]	0.2156	0.1964*	0.0112	0.1587	0.6923*	0.1721
Grazing duration	2	0.3005	0.1277	0.2142	0.2450	0.0246	0.0455	0.0421	0.6922	0.0370
Interaction	2	0.4111	0.1532	0.1322	0.2151	0.0934	0.0400	0.2928	0.1117	0.1579
Rep x treatment	10	0.6786	0.5591	0.3775	0.8511	0.0320	0.0419	0.1606	0.1289	0.1197
Total	17	0.5851	0.5313	0.5043	0.7807	0.0541	0.376	0.2183	0.1523	0.1227
24 August										
Rep.	2	1.5895	1.0132	0.2753	0.3718	0.2213	0.1629[+]	0.0542	0.2364	0.1710
Grazing intensity	1	2.8720[+]	3.5823*	0.1028	1.8948[+]	0.1387	0.0181	0.0000	0.0338	0.0265
Grazing duration	2	3.0923[+]	1.0356	0.6872	0.1957	0.1037	0.0780	0.0676	0.2432	0.3241[+]
Interaction	2	1.1430	0.4294	0.3171	0.0661	0.0547	0.0307	0.0307	0.0806	0.0487
Rep x Treatment	10	0.9365	0.5497	0.3153	0.4061	0.1313	0.0462	0.0680	0.1005	0.0832
Total	17	1.4051	0.8256	0.3420	0.4249	0.1300	0.0602	0.0579	0.1270	0.1145

15 September

	df									
Rep.	2	0.0319	0.5101*	0.3868	0.6234*	0.0097	0.0335	0.0491	0.1672	0.0363
Grazing intensity	1	0.4080	0.4171[+]	0.0018	0.3669	0.0000	0.0016	0.0032	0.0003	0.0193
Grazing duration	2	1.2601*	0.4304*	0.2384	0.1166	0.0802	0.0189	0.0224	0.1318	0.8454**
Interaction	2	0.6652	0.2332	0.1569	0.0793	0.0832	0.0076	0.0405	0.0914	0.1985*
Rep x Treatment	10	0.2611	0.0982	0.1599	0.1200	0.0506	0.0165	0.0225	0.0762	0.0329
Total	17	0.4078	0.2204	0.1862	0.1886	0.0501	0.0168	0.0266	0.0908	0.1476

6 October

	df									
Rep.	2	0.6701	0.1930	0.1951	0.0392	0.0075	0.0653	0.0950	0.0228	0.0127
Grazing intensity	1	0.0118	0.0709	0.1267	0.0841	0.0882	0.0624	0.0272	0.0356	0.1120
Grazing duration	2	0.6638	0.4534	0.3135	0.1388	0.0811	0.0155	0.0828	0.0774	0.1291[+]
Interaction	2	0.1595	0.1104	0.0106	0.0781	0.0397	0.0218	0.0004	0.0077	0.0150
Rep x Treatment	10	0.2603	0.2077	0.1236	0.0765	0.0373	0.0295	0.0496	0.0505	0.0438
Total	17	0.3295	0.2153	0.1413	0.0801	0.0422	0.0331	0.0517	0.0445	0.0508

(c) t-tests

    (i) Between grazing duration means

Species	Date	EMS	n	LSD (0.1)	(0.05)	(0.01)	(0.001)
Total Grass	24 August	9365.2	6	98.0	124.5	177.1	
Clover	"	831.8	6	29.1	37.1	52.7	
Total Grass	15 September	2610.7	6	51.7	65.7	93.5	135.3
Clover	"	328.9	6	18.4	23.3	33.2	48.0
Total Sown Grass	"	982.1	6	31.7	40.3	57.3	
Clover	6 October	437.6	6	21.2	26.9	38.3	

    (ii) Grazing intensity x Grazing duration Interaction
        (Clover, 15 September, $p < 0.05$)

	120 cow days/acre	200 cow days/acre
6 hour duration	82.0 *	114.7
24 hour duration	97.7	62.7
72 hour duration	141.3	163.3

      * rooted nodes/ft^2

n = 3
EMS = 328.9
LSD(0.1) = 25.96
(0.05) = 32.99
(0.01) = 46.93
(0.001) = 67.9

Appendix 21 : Soil Bulk Density – Experiment II

(a) Data

I	K	L	0 – 3 cm	3 – 6 cm	6 – 9 cm	0 – 9 cm
1	1	1	0.902	1.119	1.115	1.045
1	1	2	0.952	1.182	1.146	1.095
1	1	3	0.851	1.123	1.123	1.033
1	2	1	0.959	1.171	1.141	1.090
1	2	2	1.014	1.219	1.161	1.132
1	2	3	0.890	1.142	1.141	1.058
2	1	1	0.872	1.124	1.107	1.034
2	1	2	0.933	1.088	1.048	1.023
2	1	3	0.871	1.117	1.079	1.022
2	2	1	0.860	1.116	1.114	1.030
2	2	2	0.922	1.127	1.084	1.044
2	2	3	0.928	1.167	1.100	1.065
3	1	1	0.863	1.068	1.100	1.010
3	1	2	0.885	1.065	1.092	1.014
3	1	3	0.840	1.009	0.976	0.942
3	2	1	0.884	1.057	1.091	1.010
3	2	2	0.917	1.059	1.035	1.004
3.	2	3	0.927	1.112	1.098	1.046
1			0.928	1.159	1.138	1.076
2			0.898	1.123	1.089	1.036
3			0.886	1.062	1.065	1.004

(b) Analysis of Variance

	df	Mean square x 10^2			
	df	0–3	3–6	6–9	0–9
Grazing intensity	1	0.612*	0.420$^+$	0.178	0.378*
Grazing duration	2	0.502*	0.340	0.098	0.091
Interaction	2	0.066	0.086	0.132	0.090
Replicates	2	0.282	1.462***	0.821**	0.762**
Replicate x Treatment	10	0.102	0.095	0.103	0.064
Total	17	0.196	0.266	0.195	0.171

(c) <u>t-tests</u>

	Layer	EMS(10df)	n	LSD 0.1	0.05	0.01	0.001
(i) Durations	0-3 cm	1.02×10^{-3}	6	0.0335	0.0412	0.0585	
(ii) Replicates	3-6 "	0.95×10^{-3}	6	0.0323	0.0397	0.0564	0.0816
	6-9 "	1.03×10^{-3}	6	0.0335	0.0412	0.0586	0.0849
	0-9 "	0.64×10^{-3}	6	0.0265	0.0325	0.463	0.0670

Appendix 22 :   D.M. Intake and Percent Utilization – Experiment II

(a)   Data

I	K	L	M	Intake*	Utilization (%)	I	K	L	M	Intake*	Utilization (%)
1	1	1	1	9.91	76.1	2	2	1	1	3.18	50.0
1	1	1	2	9.00	62.9	2	2	1	2	2.58	46.1
1	1	1	3	10.07	65.5	2	2	1	3	4.67	66.5
1	1	2	1	11.27	74.1	2	2	2	1	3.46	45.6
1	1	2	2	10.53	70.2	2	2	2	2	3.71	55.6
1	1	2	3	8.44	52.9	2	2	2	3	4.09	65.5
1	2	1	1	4.59	61.5	3	1	1	1	5.40	48.3
1	2	1	2	5.28	72.4	3	1	1	2	8.43	66.9
1	2	1	3	4.63	61.3	3	1	1	3	6.56	55.1
1	2	2	1	5.97	63.6	3	1	2	1	9.02	63.4
1	2	2	2	5.43	68.3	3	1	2	2	11.11	74.3
1	2	2	3	5.55	65.4	3	1	2	3	10.18	71.2
2	1	1	1	6.37	49.3	3	2	1	1	2.68	41.1
2	1	1	2	8.50	67.2	3	2	1	2	3.61	56.3
2	1	1	3	7.09	56.2	3	2	1	3	2.74	46.1
2	1	2	1	5.93	50.5	3	2	2	1	5.83	72.4
2	1	2	2	8.59	63.0	3	2	2	2	7.48	81.9
2	1	2	3	9.85	66.9	3	2	2	3	6.97	76.8

* lbs D.M. per cow per day

(b) Analysis of Variance

	df	mean squares Intake	% Utilization
Grazing intensity	1	151.290**	39.59
Grazing duration	1	21.965*	492.03
Interaction	1	0.025	83.44
Replicate	2	10.700	267.40
Rep x Treatment	6	3.258	165.37
Days	2	2.460	168.32
Days x Intensity	2	0.790	43.65
Days x Duration	2	0.0003	0.98
Days x Intensity x Duration	2	0.022	0.78
Rep x Day x Treatment	16	1.288	72.96
Total	35	6.896	106.77

(c) t-test — Between grazing duration means for D.M. intake.

$$n = 6$$
$$EMS \ (16 \ df) = 1.288$$
$$LSD \ (\ 0.1 \ ) = 1.14$$
$$(\ 0.05 \ ) = 1.39$$
$$(\ 0.01 \ ) = 2.63$$

Appendix 23 : D.M. Production Between Day – Experiment II

(a) Data

I	K	L	M	Pre-	Post-	Harvest (Days from grazing) 10	20	30	40	50
1	1	1	1	1562	373	596	1084	1424	2180	2969
1	1	1	2	1718	638	817	1379	1570	2332	3435
1	1	1	3	1844	636	768	1094	1579	2184	3430
1	1	2	1	1824	472	498	899	1732	2038	2899
1	1	2	2	1801	537	572	1090	1532	2273	3586
1	1	2	3	1915	902	686	1086	1486	2286	3047
1	2	1	1	1492	575	520	746	835	1421	1927
1	2	1	2	1459	403	442	886	1203	1798	2648
1	2	1	3	1509	584	526	874	1342	1876	2631
1	2	2	1	1877	683	250	481	791	1110	1708
1	2	2	2	1589	504	488	1016	1083	1695	2781
1	2	2	3	1695	586	544	766	1211	1544	2653
2	1	1	1	1549	785	736	1034	1639	2210	3134
2	1	1	2	1519	499	706	1223	1527	2086	2786
2	1	1	3	1515	664	586	952	1540	1939	2714
2	1	2	1	1411	699	599	1014	1400	2176	2559
2	1	2	2	1636	605	707	1170	1562	2082	3561
2	1	2	3	1766	584	686	1270	1794	2243	3726
2	2	1	1	1270	635	561	747	1220	1954	2416
2	2	1	2	1119	603	538	911	1084	1461	2330
2	2	1	3	1404	471	608	761	1151	1661	2442
2	2	2	1	1517	826	319	543	791	1522	1885
2	2	2	2	1334	592	441	1001	1233	1739	2364
2	2	2	3	1248	430	425	616	1014	1582	2129
3	1	1	1	1341	693	687	1015	1526	2006	3023
3	1	1	2	1511	500	647	1232	1558	1952	3268
3	1	1	3	1428	641	601	977	1415	2093	2997
3	1	2	1	1706	624	640	808	1534	2256	3301
3	1	2	2	1793	460	555	1020	1304	2116	3564
3	2	1	1	1305	769	543	932	1493	2034	2497
3	2	1	2	1280	559	698	1147	1334	1936	2796
3	2	1	3	1189	641	612	881	1469	1915	2722
3	1	2	3	1714	493	531	1035	1484	2442	3677

3	2	2	1	1611	445	371	415	760	1508	2420
3	2	2	2	1826	330	292	598	911	1508	2423
3	2	2	3	1815	421	243	518	848	1571	2488

(c) <u>t-tests</u>

· (i) Between days

Harvest	EMS (16df)	n	LSD(0.1)	(0.05)	(0.01)	(0.001)
20 day	4810	12	49.4	60.0	82.7	113.6
50 day	74490	12	195.0	236.3	325.5	447.5

(ii) Interaction, Duration x Day at harvest day 20 (p < 0.05)

	Grazing duration (hour)	
	6	24
Day 1	926*	693
2	1130	990
3	923	881

*lb DM per acre

EMS (16 df) = 4810   n = 6
LSD (0.1) = 69.8
    (0.05) = 84.8
    (0.01) = 116.9
    (0.001) = 160.7

(iii) Interaction, Day x Duration x Intensity at harvest day 20
(p < 0.01)

Grazing intensity	120 cow days/acre		200 cow days/acre	
Grazing duration (hours)	6	24	6	24
Days 1	1044*	907	808	480
2	1278	1093	981	887
3	1008	1130	839	633

* lb D.M. per acre.

EMS (16 df) = 4810   n = 3
LSD (0.1) = 98.8
   (0.05) = 120.0
   (0.01) = 165.4
   (0.001) = 227.3

(b) Analysis of variance

Source	df	Pre-	Post-	mean squares x 10^{-4} 10	20	30	40	50
Grazing intensity	1	25.233*	1.554	28.391***	83.967**	170.433***	227.959***	577.280***
Grazing duration	1	45.878**	0.629	15.275**	17.140+	16.524	5.040	1.020
Interaction	1	2.280	0.380	2.806	4.608	17.907+	28.569	38.482*
Replicate	2	18.911+	1.414	0.509	1.717	0.212	1.156	20.440+
Rep x Treatment	6	3.462	2.058	1.036	3.683	4.710	4.1737	5.474
Day	2	0.773	3.852	0.824	19.168***	3.013	1.796	54.464**
Day x intensity	2	2.926	2.403	0.187	0.651	3.560	0.786	0.551
Day x duration	2	0.057	0.042	0.302	2.756*	0.624	3.526	12.293
Day x intensity x duration	2	0.407	0.226	0.300	3.407**	3.201	3.253	4.152
Rep x Day x Treatment	16	1.295	1.676	0.793	0.481	2.068	2.762	7.449
Total	35	4.601	1.646	1.989	5.454	8.213	10.052	27.217

(d) Relative growth rates (Analysis of variance of b values)

Source	df	mean square $(x\ 10^6)$
Treatments	3	163.6269*
Reps	2	78.7378**
Treatment x Reps	6	30.7356
Days	2	9.6970
Days x Treatments	6	5.7536
Error	16	12.3957

Appendix 24 : Botanical composition : Experiment II

(a) Data — Percent composition of treatment mean D.M. Yields

K	L	M	Ryegrass	Timothy	Cocksfoot	Poa	Other Grasses	Total Sown Grass	Total Unsown Grass	Clover	Weed	Dead
(i) Pre-grazing												
1		1	46.7	9.4	17.9	6.0	2.8	74.0	8.8	8.5	2.0	6.6
1		2	50.0	7.2	15.6	6.8	1.6	72.8	8.4	12.7	1.9	4.3
1		3	46.6	10.6	11.6	6.6	3.0	68.8	9.6	12.1	2.4	7.0
2		1	48.3	9.5	12.2	7.3	3.3	70.0	10.7	10.9	1.5	6.9
2		2	42.9	10.8	16.5	8.5	2.0	70.1	10.4	10.6	3.0	5.9
2		3	44.4	7.9	14.1	6.5	5.2	66.4	11.8	13.3	2.0	6.4
	1	1	45.1	10.3	16.0	7.4	3.5	71.3	11.0	8.6	1.9	7.2
	1	2	44.3	10.7	16.6	8.3	1.1	71.6	9.3	11.6	3.3	4.2
	1	3	43.1	8.9	12.9	7.9	4.1	64.9	12.0	13.9	2.8	6.3
	2	1	49.9	8.6	14.1	6.0	2.6	72.7	8.6	10.8	1.6	6.3
	2	2	48.6	7.2	15.5	7.0	2.5	71.3	9.5	11.6	1.6	6.0
	2	3	47.9	9.6	12.8	5.1	4.2	70.3	9.4	11.5	1.7	7.1
(ii) Regrowth day 10												
1		1	37.6	14.5	19.3	1.9	2.6	71.4	4.5	9.1	3.1	12.0
1		2	48.7	6.4	12.4	5.1	1.8	67.5	6.9	11.9	1.9	11.8
1		3	47.0	11.0	12.7	4.6	1.7	70.6	6.2	10.5	2.3	10.4
2		1	36.1	13.8	14.8	3.3	2.0	62.0	5.4	14.0	2.6	15.9
2		2	42.4	12.0	12.7	6.0	3.0	67.1	8.9	8.4	3.8	11.7
2		3	29.9	12.3	14.7	5.6	4.3	56.9	9.9	14.6	3.1	15.6
	1	1	31.9	13.2	18.9	3.0	3.0	64.1	6.0	11.9	3.8	14.3

1	2	44.1	7.2	14.8	6.5	1.8	66.1	8.3	10.3	3.5	11.8
1	3	37.2	13.1	10.6	6.1	3.8	60.9	9.9	14.3	3.6	11.3
2	1	41.7	15.1	15.2	2.3	1.6	69.3	3.9	11.2	2.0	13.6
2	2	47.0	11.1	10.4	4.5	3.0	68.6	7.6	9.9	2.2	11.8
2	3	39.7	10.1	16.9	4.1	2.2	66.6	6.2	10.8	1.7	14.6

(iii) Regrowth day 30

1	1	46.0	13.0	12.8	6.1	1.2	71.8	7.3	14.6	3.8	2.5
1	2	46.6	10.7	10.8	5.8	0.9	68.1	6.7	18.9	3.9	2.4
1	3	47.3	10.1	10.3	6.5	2.0	67.7	8.6	15.9	4.1	3.7
2	1	45.1	16.0	8.0	6.6	1.4	69.1	8.1	15.1	4.2	3.5
2	2	38.9	15.3	9.4	8.0	3.3	63.7	11.2	16.9	5.4	2.7
2	3	37.4	16.2	9.5	8.5	3.6	63.2	12.1	17.0	4.4	3.3
1	1	41.2	15.1	10.7	6.4	1.8	67.0	8.3	17.2	4.5	3.0
1	2	40.2	11.8	8.2	8.7	2.9	60.2	11.6	19.3	5.6	3.2
1	3	37.2	14.1	8.7	9.4	3.7	60.0	13.1	18.4	5.2	3.3
2	1	49.8	13.9	10.1	6.3	0.8	73.8	7.1	12.5	3.5	3.0
2	2	45.4	14.2	12.0	5.1	1.3	71.6	6.4	16.4	3.6	1.9
2	3	47.5	12.2	11.1	5.7	1.9	70.8	7.7	14.5	3.3	3.6

(iv) Regrowth day 50

1	1	43.7	11.6	10.1	6.5	3.9	65.4	10.4	14.4	5.3	4.6
1	2	56.7	9.7	8.3	5.1	1.7	74.7	6.9	12.0	2.0	4.4
1	3	49.4	11.4	11.6	6.8	3.6	72.4	9.1	12.4	2.1	4.0

2	1	40.1	11.2	7.3	8.7	3.9	58.6	13.4	17.9	5.3	4.8
2	2	45.9	11.5	9.0	6.1	5.8	66.3	12.0	13.8	4.2	3.6
2	3	43.9	11.1	11.3	7.0	4.5	66.3	11.5	12.6	6.1	3.5
	1	1	37.3	10.3	10.2	8.9	4.7	57.8	13.5	18.4	5.7	4.6
	1	2	45.0	10.3	8.6	7.3	5.2	64.0	12.5	15.2	3.5	4.9
	1	3	41.9	13.2	9.0	8.0	5.6	64.0	12.3	14.5	5.1	3.8
	2	1	46.6	12.4	7.2	6.3	3.1	66.3	10.3	13.9	4.8	4.8
	2	2	57.6	10.8	8.7	4.0	2.3	77.1	6.3	10.6	2.8	3.1
	2	3	51.4	9.3	13.8	5.8	2.5	74.4	8.4	10.5	3.0	3.7

(b) Data — Total sown grass and ryegrass D.M. yields day 10 and day 50.

K	L	M	Day 10		Day 50	
			Total Sown Grass	Ryegrass	Total Sown Grass	Ryegrass
1	1	1	475.6	225.4	1940	1305
1	1	2	495.7	336.0	2196	1634
1	1	3	446.0	297.7	1975	1335
1	2	1	412.6	236.7	2007	1329
1	2	2	405.3	317.9	2851	2202
1	2	3	463.9	309.9	2737	1885
2	1	1	314.4	166.4	1172	713
2	1	2	341.7	221.7	1524	1006
2	1	3	312.2	169.9	1605	1026
2	2	1	203.7	127.8	1327	988
2	2	2	282.1	171.9	1879	1356
2	2	3	238.5	121.9	1730	1198

(c) Analysis of variance – D.M. yield

Source	df	Mean square $(\times 10^{-4})$ Ryegrass (day 10)	Ryegrass (day 50)	Total Sown Grass (day 50)
Grazing intensity	1	13.841**	289.53**	499.60**
Grazing duration	1	0.430	93.91	112.17*
Interaction	1	0.503	2.98	18.05
Replicate	2	0.512	59.75*	52.18+
Rep x Treatment	6	0.513	10.00	14.16
Day	2	1.591*	65.86***	84.27**
Day x Intensity	2	0.418	6.56	1.42
Day x Duration	2	0.035	7.51	13.48
Day x Intensity x duration	2	0.016	8.02	9.86
Rep x Day x Treatment	16	0.380	4.90	8.43
Total	35	0.832	23.43	33.49

(d) t-tests – Between days D.M. yield

Comparison	EMS	n	LSD (0.1)	(0.05)	(0.01)	(0.001)
Ryegrass (day 10)	3800	12	44.0	53.4	73.6	101.1
Ryegrass (day 50)	49000	12	157.8	191.6	263.9	362.8
Total Sown grass (day 50)	84300	12	207.1	251.4	246.4	476.2

Appendix 25 : Tiller Density – Experiment II

(a) Data

I	K	L	M	Total grass	Total sown Grass	Total Unsown Grass	Clover	Ryegrass	Timothy	Cocksfoot	Poa	Other Grass
8 August												
1	1	1	1	584	467	117	190	329	105	37	53	64
1	1	1	2	647	526	121	133	380	137	9	82	39
1	1	1	3	408	195	213	142	101	53	41	183	30
1	1	2	1	377	334	43	185	215	96	23	32	11
1	1	2	2	467	352	115	115	222	96	34	71	44
1	1	2	3	589	470	119	80	305	89	76	57	62
1	2	1	1	619	486	133	117	300	126	60	101	32
1	2	1	2	682	488	194	188	243	151	94	128	66
1	2	1	3	497	287	210	147	165	69	53	137	73
1	2	2	1	612	404	208	126	243	85	76	137	71
1	2	2	3	671	490	181	117	316	85	89	89	92
2	1	1	1	472	364	108	98	206	89	69	94	14
2	1	1	2	524	334	190	188	144	103	87	133	57
2	1	1	3	593	428	164	156	259	66	103	69	96
2	1	2	1	685	337	348	204	197	126	14	190	158
2	1	2	2	514	329	185	192	137	137	55	48	137
2	1	2	3	489	345	144	133	199	98	48	110	34
2	2	1	1	462	284	178	142	112	165	7	57	121
2	2	1	2	713	369	344	151	211	135	23	115	229

2	2	1	3	751	447	304	124	236	165	46	144	160
2	2	2	1	373	234	139	126	71	131	32	50	89
2	2	2	2	493	289	204	156	108	126	55	103	101
2	2	2	3	572	329	243	213	185	110	34	76	167
3	1	1	1	373	320	53	144	169	73	78	44	9
3	1	1	2	524	391	133	153	263	78	50	64	69
3	1	1	3	405	279	126	169	126	98	55	46	80
3	1	2	1	531	439	92	117	256	105	78	32	60
3	1	2	2	564	493	71	192	364	85	44	48	23
3	1	2	3	385	337	48	151	234	80	23	37	11
3	2	1	1	421	213	208	156	55	101	57	64	144
3	2	1	2	611	414	197	185	231	119	64	124	73
3	2	1	3	735	449	.286	148	174	211	64	151	135
3	2	2	1	427	327	100	199	188	112	27	82	18
3	2	2	2	541	426	115	179	197	156	73	78	37
3	2	2	3	503	403	100	158	188	46	169	73	27
1	2	2	2	451	247	204	110	128	69	50	110	94

24 August

1	1	1	1	333	268	65	82	126	89	53	44	21
1	1	1	2	349	213	136	124	126	76	11	92	44
1	1	1	3	567	524	43	110	350	96	78	34	9
1	1	2	1	291	254	37	73	176	55	23	32	5
1	1	2	2	209	181	28	76	98	69	14	21	7

1	1	2	3	339	273	66	46	165	92	16	39	27
1	2	1	1	267	228	39	85	73	128	27	23	16
1	2	1	2	351	264	87	124	167	92	5	76	11
1	2	1	3	395	338	57	94	137	169	32	55	2
1	2	2	1	155	116	39	85	73	25	18	21	18
1	2	2	2	380	293	87	37	119	103	71	48	39
1	2	2	3	352	245	107	46	160	62	23	66	41
2	1	1	1	330	259	71	55	131	55	73	39	32
2	1	1	2	483	332	151	121	165	140	27	126	25
2	1	1	3	578	400	178	71	222	128	50	137	41
2	1	2	1	545	295	250	135	158	112	25	206	44
2	1	2	2	458	384	74	119	181	137	66	44	30
2	1	2	3	446	379	78	92	176	137	55	44	34
2	2	1	1	474	305	169	135	78	133	94	87	82
2	2	1	2	756	456	300	112	245	103	108	181	119
2	2	1	3	472	323	149	142	117	94	112	76	73
2	2	2	1	132	103	29	57	39	50	14	27	2
2	2	2	2	364	277	87	144	94	128	55	80	7
2	2	2	3	440	270	170	153	110	137	23	147	23
3	1	1	1	494	436	58	144	188	179	69	21	37
3	1	1	2	436	307	129	135	142	94	71	92	37
3	1	1	3	466	358	108	140	156	149	53	69	39
3	1	2	1	523	404	119	66	204	76	124	94	25
3	1	2	2	361	325	36	126	165	89	71	34	2

3	1	2	3	395	368	27	44	169	169	30	18	9
3	2	1	1	407	237	170	181	82	98	57	124	46
3	2	1	2	510	343	337	153	188	98	57	133	34
3	2	1	3	551	313	238	183	103	128	82	192	46
3	2	2	1	153	133	20	34	60	55	18	2	18
3	2	2	2	119	108	11	39	32	44	32	9	2
3	2	2	3	86	78	8	85	16	41	21	7	1

15 September

1	1	1	1	403	293	110	66	176	64	53	89	21
1	1	1	2	330	268	62	96	167	76	25	57	5
1	1	1	3	390	259	131	85	165	62	32	117	14
1	1	2	1	269	215	54	71	94	71	50	53	1
1	1	2	2	348	277	71	126	174	64	39	69	2
1	1	2	3	355	249	106	96	169	55	25	101	5
1	2	1	1	295	239	56	66	163	62	14	55	1
1	2	1	2	439	366	73	128	268	87	11	66	7
1	2	1	3	298	220	78	89	117	94	9	76	2
1	2	2	1	222	195	27	71	142	30	23	11	16
1	2	2	2	222	135	87	46	78	50	7	80	7
1	2	2	3	345	249	96	32	144	57	47	66	30
2	1	1	1	313	236	77	55	126	39	71	66	11
2	1	1	2	266	176	90	105	110	41	25	85	5
2	1	1	3	536	394	142	57	261	76	57	110	32

2	1	2	1	376	277	99	147	188	78	11	78	21
2	1	2	2	295	213	82	76	117	66	30	73	9
2	1	2	3	297	231	66	85	167	32	32	57	9
2	2	1	1	305	181	124	131	92	55	34	78	46
2	2	1	2	462	270	192	92	89	115	66	151	41
2	2	1	3	433	220	213	137	94	69	57	142	71
2	2	2	1	174	121	53	73	71	41	9	44	9
2	2	2	2	314	199	115	82	108	82	9	92	23
2	2	2	3	317	147	170	82	57	60	30	101	69
3	1	1	1	315	214	101	64	92	85	37	64	37
3	1	1	2	243	179	64	92	87	55	37	32	32
3	1	1	3	428	307	89	119	206	69	32	87	2
3	1	2	1	513	396	117	87	300	64	32	101	16
3	1	2	2	353	268	85	144	167	76	24	80	5
3	1	2	3	226	148	78	46	87	34	27	57	21
3	2	1	1	337	208	129	126	82	92	34	85	44
3	2	1	2	578	447	131	115	236	172	39	101	30
3	2	1	3	463	238	225	149	126	62	50	172	53
3	2	2	1	178	168	10	34	115	32	21	5	5
3	2	2	2	324	292	32	82	163	69	60	23	9
3	2	2	3	147	124	23	60	92	21	11	21	2

6 October

1	1	1	1	231	165	66	80	87	37	41	41	25
1	1	1	2	259	204	82	87	124	39	14	80	5
1	1	1	3	141	63	78	62	44	14	5	73	2

1	1	2	1	260	213	47	39	142	46	25	46	1
1	1	2	2	218	171	47	94	98	66	7	46	1
1	1	2	3	292	259	33	50	206	39	14	32	1
1	2	1	2	234	190	44	89	133	50	7	39	5
1	2	1	3	266	216	50	87	131	80	5	41	9
1	2	2	1	209	118	91	37	89	18	11	80	11
1	2	2	2	279	144	132	69	110	23	11	105	27
1	2	2	3	188	92	96	69	41	44	7	66	30
2	1	1	1	288	240	48	44	142	11	87	37	11
2	1	1	2	294	183	111	11	137	23	23	110	1
2	1	1	3	289	181	108	66	119	37	25	69	39
2	1	2	1	176	89	87	89	50	23	16	60	27
2	1	2	2	291	165	126	53	105	30	30	112	14
2	1	2	3	195	171	24	48	112	32	27	23	1
2	2	1	1	349	280	69	80	156	115	9	44	25
2	2	1	2	373	247	126	115	135	89	23	50	76
2	2	1	3	361	239	122	62	131	76	32	69	53
2	2	2	1	187	151	36	55	80	55	16	34	2
2	2	2	2	201	118	83	46	64	27	27	76	7
2	2	2	3	282	158	124	101	64	53	41	87	37
3	1	1	1	341	279	62	76	142	64	73	23	39
3	1	1	2	346	220	126	73	126	71	73	62	64
3	1	1	3	340	251	89	115	167	57	27	71	18

3	1	2	1	281	194	87	30	119	48	27	82	5
3	1	2	2	217	162	55	78	105	48	9	39	16
3	1	2	3	287	216	71	66	181	21	14	64	7
3	2	1	1	290	165	125	87	103	44	18	98	27
3	2	1	2	293	162	131	24	112	39	11	115	16
3	2	1	3	361	187	174	147	89	64	34	117	57
3	2	2	1	270	208	62	66	133	48	27	57	5
3	2	2	2	179	156	23	64	76	48	32	18	5
3	2	2	3	164	154	10	82	108	32	14	9	1
1	2	1	1	313	246	67	80	137	82	27	53	14

(b) Analysis of Variance

Source	df	Total grass	Total Sown Grass	Total Unsown Grass	Clover	Ryegrass	Timothy	Cocks-foot	Poa	Other Grass
					Mean squares		$(\times 10^{-2})$			
8 August										
Grazing intensity	1	279.45[+]	6.59	372.49[*]	0.03	158.34	55.75*	6.17	50.41	148.43[+]
Grazing duration	1	167.70	6.76	106.78	0.04	0.67	12.48	0.002	37.21	18.06
Interaction	1	234.60	49.00	69.45	0.11	18.06	51.84[*]	20.40	1.78	48.77
Replicate	2	101.12	91.43	226.80	21.82	163.10	18.01	9.45	32.41	128.84
Rep x Treatment	6	60.63	43.37	53.97	11.24	41.98	6.17	17.02	19.55	29.55
Day	2	151.11	42.18	40.68	8.31	17.16	10.57	12.78	12.30	8.17
Day x Intensity	2	199.55	104.22	21.41	5.23	53.19	1.74	5.20	6.16	7.00
Day x Duration	2	119.53	94.95	79.08[+]	7.04	97.09	4.86	3.98	35.72	8.76
Day x Intensity x Duration	2	2.95	16.70	8.24	15.99	15.73	8.58	6.16	3.92	16.88
Day x Rep x Treatment	16	118.40	98.78	25.30	11.74	62.39	11.45	8.41	13.91	15.03
Total	35	116.81	74.34	58.00	10.64	60.57	12.22	9.67	17.44	27.81
24 August										
Grazing intensity	1	426.42	650.25*	56.25	4.69	403.34**	17.92	1.00	7.84	3.48
Grazing duration	1	1696.07*	558.53*	408.04[+]	149.65[+]	100.33[+]	60.84	36.00	121.73[+]	40.11
Interaction	1	652.80	250.69	162.14	29.16	38.65	29.88	15.73	48.53	8.60
Replicate	2	477.47	73.32	174.47	34.23	16.34	18.46	28.95	87.80	17.19
Rep x Treatment	6	209.22	91.05	87.23	30.11	19.69	20.03	17.27	29.12	50.38

	df									
Day	2	210.36[+]	144.11[+]	33.19	6.66	52.76	25.94	0.09	10.59	0.04
Day x Intensity	2	261.81[+]	162.65[+]	53.72[+]	18.05	85.47*	2.25	9.53	28.51	0.57
Day x Duration	2	63.18	19.50	118.51**	0.54	34.37	16.43	15.68[+]	54.05*	2.44
Day x Intensity x Duration	2	133.68	24.47	52.32[+]	10.27	55.38[+]	7.22	0.54	47.73[+]	0.64
Day x Rep x Treatment	16	74.44	49.83	18.41	7.31	19.82	10.07	4.70	13.82	1.77
Total	35	214.71	104.32	65.96	17.74	41.89	15.16	9.75	29.46	6.13
15 September	1									
Grazing Intensity	1	45.11	93.77[+]	12.25	0.13	105.40[+]	5.68	3.24	0.01	13.08
Grazing duration	1	675.13*	182.70*	142.40	30.62*	13.94	42.90*	10.45	75.40	10.56
Interaction	1	383.51*	138.85*	69.44	103.36**	38.03	31.92*	0.001	55.01	0.84
Replicate	2	9.11	27.16	49.36	6.09	31.59	1.35	2.01	16.43	11.72
Rep x Treatment	6	50.50	17.51	39.85	4.82	26.08	4.36	5.63	17.41	5.56
Day	2	71.48	29.82	47.03**	8.47	3.24	17.60*	0.29	29.79**	3.86
Day x Intensity	2	296.67*	173.55*	32.84*	5.22	68.86	17.14*	4.33	19.17*	3.63
Day x Duration	2	83.46	51.89	8.25	10.12	42.43	1.80	0.85	11.15	0.61
Day x Intensity x Duration	2	162.65[+]	124.02[+]	1.73	2.40	56.10	9.04	1.60	1.28	0.09
Day x Rep x Treatment	16	54.53	43.17	6.84	8.40	31.25	3.76	2.46	4.27	1.82
Total	35	100.74	57.83	24.32	10.34	34.81	7.45	3.00	13.11	3.62

6 October

Source	df									
Grazing Intensity	1	0.69	10.56	13.20	12.13	27.39	21.93	5.06*	2.15	4.69
Grazing duration	1	397.34*	168.57	54.76	18.63	30.62	23.52	4.62*	6.76	23.04
Interaction	1	90.88	65.88	8.59	4.34	42.68	23.52	7.93*	0.28	0.19
Replicate	2	55.34	15.53	12.35	4.56	6.10	0.47	7.44*	1.09	6.11
Rep x Treatment	6	52.30	61.91	35.10	5.18	25.67	11.49	0.72	22.89	6.20
Day	2	0.13	11.28	11.94	8.27	1.09	0.45	6.08*	8.38	0.93
Day x Intensity	2	4.87	1.77	7.07	3.32	17.43	5.65[+]	8.46**	3.63	4.10
Day x Duration	2	1.51	21.25	11.63	4.15	13.17	0.50	5.20*	10.31	0.4
Day x Intensity x Duration	2	18.58	32.55[+]	5.96	4.58	19.49[+]	0.54	4.19	6.38[+]	0.12
Day x Rep X Treatment	16	24.20	11.11	8.39	8.34	6.59	1.96	1.18	5.30	2.94
Total	35	38.60	27.40	14.62	7.13	13.56	5.27	2.96	8.31	14.62

(c) t-tests

(i) Total grass

24 August – grazing duration x Day (p < 0.05)

	120 cow days/acre	200 cow days/acre
Day 1	419.3*	264.7
2	382.7	413.3
3	465.2	382.7

* tillers/ft^2

$$n = 6$$
$$EMS(16\ df) = 7444$$
$$LSD\ (\ 0.1\ ) = 87.0$$
$$(\ 0.05) = 105.7$$
$$(\ 0.01) = 145.6$$
$$(0.001) = 200.1$$

15 September – grazing duration x Day (p < 0.05)

	120 cow days/acre	200 cow days/acre
Day 1	365*	252
2	306	390
3	372	334

* tillers/ft^2

$$n = 6$$
$$EMS(16\ df) = 5453$$
$$LSD\ (\ 0.1\ ) = 74.4$$
$$(0.05\ ) = 90.4$$
$$(0.01\ ) = 124.5$$

15 September – grazing duration x grazing intensity x day $(p < 0.1)$

	120 cow days/acre		200 cow days/acre	
	'6 hour'	'24 hour'	'6 hour'	'24 hour'
Day 1	344*	386	312	191
2	280	332	493	287
3	451	293	398	270

* tillers/ft^2

n = 3
EMS (16 df) = 5453
LSD (0.1) = 105
(0.05) = 128
(0.01) = 176

(ii) Total Sown Grass

24 August – Day $(p < 0.1)$

Day 1	253 tillers/ft^2
2	290 "
3	322 "

n = 12
EMS (16df) = 4983
LSD (0.1) = 50.3
(0.05) = 61.1
(0.01) = 84.2

24 August – day x intensity $(p < 0.1)$

	120 cow days/acre	200 cow days/acre
Day 1	319*	187
2	290	290
3	384	261

* tillers/ft^2

EMS (16df) = 4983   n = 6
LSD (0.1) = 71.1   (0.01) = 119.0
(0.05) = 86.4   (0.001) = 163.6

<u>15 September</u> — day x intensity (p $<$ 0.05)

	120 cow days/acre	200 cow days/acre
Day 1	272 tillers/ft^2	185 tillers/ft^2
2	230 "	285 "
3	265 "	200 "

EMS (16df) = 4317   n = 6
LSD (0.1) = 66.2
(0.05) = 80.4
(0.01) = 110.8

<u>15 September</u> — day x intensity x duration (p $<$ 0.1)

	120 cow days/acre		200 cow days/acre	
	'6 hour'	'24 hour'	'6 hour'	'24 hour'
Day 1	248*	296	209	161
2	208	252	361	209
3	320	209	226	173

* tillers/ft^2

EMS (16df) = 4317   n = 3
LSD (0.1) = 162.2
(0.05) = 196.9
(0.01) = 271.4

<u>6 October</u> — day x intensity x duration (p $<$ 0.1)

	120 cow days/acre		200 cow days/acre	
	'6 hour'	'24 hour'	'6 hour'	'24 hour'
Day 1	228*	165	230	159
2	202	166	200	139
3	165	215	214	135

* tillers/ft^2

EMS (16df) = 1111   n = 3
LSD (0.1) = 47.5
(0.05) = 57.7
(0.01) = 79.5

(iii) <u>Total Unsown Grass species</u>

<u>8 August</u> – day x duration (p $<$ 0.1)

	6 hour	24 hour
Day 1	133*	155
2	197	149
3	217	139

* tillers/ft^2

EMS (16df) = 2530   n = 6
LSD (0.1) = 50.7
  (0.05) = 61.5
  (0.01) = 84.8

<u>24 August</u> – day x duration (p $<$ 0.01), day x intensity
(p   0.1)

	6 hour	24 hour	120 cow days/acre	200 cow days/acre
Day 1	95*	82	100	78
2	190	54	92	152
3	129	76	83	122

* tillers/ft^2

EMS (16df) = 1841   n = 6
LSD (0.1) = 43.2
  (0.05) = 52.5
  (0.01) = 72.4
  (0.001) = 99.5

<u>24 August</u> – day x duration x intensity (p $<$ 0.1)

	120 cow days/acre		200 cow days/acre	
	'6 hour'	'24 hour'	'6 hour'	'24 hour'
Day 1	65*	135	126	29
2	139	46	241	62
3	110	57	148	95

* tillers/ft^2

EMS (16df) = 1841   n = 3
LSD (0.1) = 61.2
    (0.05) = 74.3
    (0.01) = 102.3
    (0.001) = 140.6

15 September — Day (p < 0.01)

Day 1   80.0 tillers/ft^2
    2   90.0
    3   118.0

EMS (16df) = 684.0   n = 12
LSD (0.1) = 18.6
    (0.05) = 22.6
    (0.01) = 31.2
    (0.001) = 42.9

15 September — day x duration (p < 0.05)

		'6 hour'	'24 hour'
Day	1	100*	60
	2	102	79
	3	146	90

* tillers/ft^2

EMS (16df) = 839.5
LSD (0.1) = 29.2
    (0.05) = 35.3
    (0.01) = 48.9
    (0.001) = 67.2

Appendix 26 : Experiment II – Soil Bulk Density

(a) Data (gm/cc)

I	K	L	M	0 – 3 cm	3 – 6 cm	6 – 9 cm	0 – 9 cm
1	1	1	1	0.900	1.068	1.122	1.030
1	1	1	2	0.931	1.140	1.062	1.044
1	1	1	3	0.075	1.150	1.161	1.062
1	1	2	1	1.028	1.243	1.161	1.144
1	1	2	2	0.957	1.173	1.115	1.082
1	1	2	3	0.888	1.129	1.161	1.058
1	2	1	1	0.947	1.129	1.165	1.080
1	2	1	2	0.972	1.169	1.133	1.091
1	2	1	3	0.957	1.215	1.125	1.099
1	2	2	1	1.060	1.248	1.182	1.163
1	2	2	2	1.004	1.237	1.175	1.139
1	2	2	3	0.978	1.173	1.126	1.093
2	1	1	1	0.878	1.160	1.127	1.055
2	1	1	2	0.837	1.080	1.083	1.000
2	1	1	3	0.900	1.131	1.111	1.047
2	1	2	1	0.928	1.049	1.038	1.005
2	1	2	2	0.978	1.093	1.045	1.039
2	1	2	3	0.894	1.121	1.061	1.025
2	2	1	1	0.890	1.130	1.112	1.044
2	2	1	2	0.841	1.089	1.119	1.017
2	2	1	3	0.848	1.130	1.110	1.029
2	2	2	1	0.973	1.125	1.098	1.065
2	2	2	2	0.915	1.140	1.058	1.037
2	2	2	3	0.879	1.117	1.095	1.030
3	1	1	1	0.874	1.038	1.088	1.000
3	1	1	2	0.869	1.083	1.092	1.014
3	1	1	3	0.846	1.083	1.121	1.016
3	1	2	1	0.889	1.107	1.148	1.048
3	1	2	2	0.863	1.049	1.083	0.998
3	1	2	3	0.902	1.039	1.045	0.995
3	2	1	1	0.836	1.041	1.083	0.986

				0-3cm	3-6cm	6-9cm	0-9cm
3	2	1	2	0.890	1.062	1.084	1.012
3	2	1	3	0.925	1.068	1.106	1.033
3	2	2	1	0.928	1.099	1.053	1.027
3	2	2	2	0.898	1.051	1.003	0.984
3	2	2	3	0.925	1.027	1.050	1.001

(b) Analysis of Variance

Source	df	Mean squares x 10^{-4}			
		0-3cm	3-6cm	6-9cm	0-9cm
Grazing Intensity	1	51.10	27.40	0.70	19.90
Grazing Duration	1	210.7**	17.90	26.10	20.80
Interaction	1	0.30	3.50	2.10	0.10
Replicate	2	1779.0**	367.4**	131.1*	208.2**
Rep x Treatment	6	15.10	22.60	27.10	13.20
Days	2	20.60	1.10	22.90$^+$	8.60
Day x Intensity	2	3.10	5.00	4.10	0.10
Day x Duration	2	28.00	47.90$^+$	6.70	24.20*
Day x Intensity x Duration	2	4.50	2.80	5.50	0.60
Rep x Day x Treatment	16	13.20	13.40	7.20	4.80
Total	35	29.50	35.40	18.50	19.50

(c) t-tests

 (i) Between Days (6 – 9 cm layer $p < 0.1$)

	Day 1	Day 2	Day 3
Soil Bulk density (gm/cc)	1.115	1.088	1.106

EMS (16df) = 0.00072   n = 12
LSD (0.1) = 0.019
    (0.05) = 0.023
    (0.01) = 0.032

(ii) Day x Grazing Duration interaction (3-6cm layer p <0.1)

		Grazing Duration (hours)	
		6	24
Days	1	1.094*	1.145
	2	1.104	1.124
	3	1.130	1.101

*Soil Bulk density (gm/cc)

EMS (16df) = 0.00134   n = 6
LSD (0.1) = 0.037
    (0.05) = 0.045
    (0.01) = 0.062

(iii) Day x Grazing Duration interaction (0-9cm layer p <0.05)

		Grazing duration (hours)	
		6	24
Days	1	1.033*	1.075
	2	1.030	1.047
	3	1.048	1.034

* Soil Bulk density (gm/cc)

EMS (16df) = 0.00048   n = 6
LSD (0.1) = 0.016
    (0.05) = 0.019
    (0.01) = 0.026
    (0.001) = 0.036

Appendix 27 : Experiment II – D.M. utilization and Intake

(a) Data

I	K	D.M. Intake (lb DM/cow/day)	% utilization
(i) Grazed			
1	1	9.11	64.8
1	2	4.97	62.2
2	1	7.71	60.8
2	2	3.95	55.9
3	1	8.79	65.5
3	2	5.09	64.5
(ii) Control			
1	1	8.34	57.3
1	2	6.15	70.3
2	1	4.88	41.6
2	2	4.58	65.1
3	1	10.7	66.0
3	2	7.66	79.0

(b) Analysis of variance

Source	df	m.s. D.M. intake	m.s.% Utilization
Defoliation intensity	1	24.3675**	139.40*
Defoliation treatment	1	0.5896	2.74
Interaction	1	3.1008*	280.72**
Replicate	2	7.9892	167.84*
Replicate x Treatment	6	1.2669	19.88
Total	11	4.6943	79.80

Appendix 28 : Botanical Components, Cut v's Grazed — Experiment II

Percent contribution of botanical components of treatment means.

	Ryegrass	Timothy	Cocksfoot	Poa	Other Grasses	Total Sown Grass	Total Unsown Grass	Clover	Weed	Dead
(i) Pre-grazing										
grazed	45.5	9.0	15.2	6.6	3.6	68.7	10.2	12.6	2.2	6.3
cut	40.4	9.7	9.5	6.5	4.9	60.0	11.5	18.5	0.9	9.4
(ii) Regrowth day 10										
grazed	38.0	11.5	13.8	5.1	2.9	63.1	8.0	12.8	3.3	12.8
cut	35.3	11.7	13.4	8.4	4.9	60.4	13.3	14.0	4.8	7.6
(iii) Regrowth day 30										
grazed	42.4	13.4	10.3	7.2	2.2	66.1	9.4	17.5	4.0	3.0
cut	39.8	7.5	10.5	5.1	7.7	57.8	12.8	19.5	3.9	6.0
(iv) Regrowth day 50										
grazed	45.1	12.3	10.2	6.9	4.1	67.6	10.9	13.5	4.0	3.9
cut	33.9	9.7	14.3	9.2	9.0	57.9	18.2	16.0	3.3	4.5

Appendix 29 : Experiment II — Tiller Density

(a) Data

I	K	Ryegrass	Timothy	Cocksfoot	Poa	Other grass	Total grass	Clover	Total Sown Grass	Total Unsown Grass
(i)	24 August — grazed									
1	1	174	77	40	64	38	392	96	291	101
1	2	94	90	26	51	29	291	81	211	80
2	1	140	146	61	95	31	474	97	347	126
2	2	106	98	64	98	39	403	134	268	136
3	1	211	108	65	54	17	454	119	384	71
3	2	130	91	57	90	19	387	121	278	109
			— cut							
1	1	311	101	39	27	55	533	128	451	82
1	2	71	124	128	158	119	600	176	323	277
2	1	174	215	27	188	218	822	218	416	406
2	2	128	202	57	92	115	594	135	387	207
3	1	254	76	46	121	71	568	202	376	192
3	2	389	103	23	172	44	731	229	515	216
(ii)	15 September — grazed									
1	1	178	77	26	83	21	385	113	281	104
1	2	175	61	20	55	12	322	90	256	66
2	1	140	68	37	91	25	362	105	245	116

2	2	86	58	39	97	39	318	128	183	135
3	1	171	58	33	52	15	333	103	268	67
3	2	142	84	33	72	18	350	125	259	91

– cut

1	1	82	103	48	44	78	355	103	233	122
1	2	211	85	34	76	87	493	103	330	163
2	1	76	71	60	119	94	420	151	207	213
2	2	71	108	16	128	80	403	103	195	208
3	1	190	37	48	105	5	385	142	275	110
3	2	245	98	32	98	25	498	128	375	123

(iii) <u>6 October</u> – grazed

1	1	97	40	19	57	18	233	72	160	76
1	2	101	36	12	66	18	233	83	149	84
2	1	117	25	52	74	25	293	74	194	99
2	2	97	63	21	74	52	307	91	180	126
3	1	128	40	22	59	17	266	63	190	76
3	2	103	49	25	77	14	267	83	177	91

– cut

1	1	108	39	39	87	21	294	96	186	108
1	2	108	30	60	27	62	287	85	198	89
2	1	69	69	14	92	133	377	115	152	225
2	2	105	73	14	92	147	431	126	192	239
3	1	101	101	34	41	25	302	101	236	66
3	2	119	37	41	32	5	234	117	197	37

(b) Analysis of variance

mean square x 10^{-2}

Source	df	Ryegrass	Timothy	Cocksfoot	Poa	Other grasses	Total grass	Clover	Total Sown Grass	Total Unsown Grass
(i) 24 August										
Defoliation intensity	1	99.76	0.19	4.94	10.45	3.52	46.81	0.21	66.74	1.84
Defoliation method	1	185.65	37.10	0.04	78.03	168.00*	1744.84**	161.33**	395.60**	477.54*
Interaction	1	1.61	6.60	11.02	3.00	3.74	48.40	0.85	50.84	0.04
Replicate	2	130.02	63.60*	1.11	20.83	40.77	148.30	22.62	47.97	82.04
Rep x Treatment	6	73.60	10.21	11.47	24.58	19.97	71.80	10.66	32.23	73.11
Total	11	89.88	21.13	7.91	25.51	34.24	233.40	24.69	72.95	98.38
(ii) 15 September										
Defoliation intensity	1	7.21	5.33	5.07*	0.85	0.44	17.28	1.47	6.60	2.43
Defoliation method	1	0.24	7.68	2.08	12.00	47.60*	195.21**	3.85	12.61	108.00**
Interaction	1	58.52	5.33	4.08+	1.08	0.04	87.48+	5.60	65.80*	1.61
Replicate	2	93.98+	1.51	0.39	19.90+	21.02+	2.83	5.78	83.02*	54.22*
Rep x Treatment	6	18.86	4.55	0.77	3.84	5.09	15.39	2.43	9.59	4.77
Total	11	33.37	4.42	1.51	6.98	10.97	36.18	3.37	29.18	22.65

(iii) 6 October

Defoliation intensity	1	0.14	0.56	0.04	1.47	2.90	0.03	3.41	0.52	0.21
Defoliation method	1	0.91	7.68	2.17	1.08	51.67^+	88.56^+	25.33**	10.27	37.45
Interaction	1	7.52^+	10.45	3.31	7.70	0.10	1.08	0.85	2.17	5.88
Replicate	2	2.51	5.82	0.56	10.39	6.51*	102.39*	3.10	7.83	122.23*
Rep x Treatment	6	1.64	3.90	3.44	3.93	11.49	15.08	1.02	5.50	20.83
Total	11	2.13	4.88	2.48	4.96	22.42	35.00	3.80	5.60	37.55

(c) <u>t-tests</u> — 15 September, Defoliation intensity x defoliation method interaction

(i) Total grass (p 0.1)

	120 cow days/acre	200 cow days/acre
grazed	360.0*	330.0
cut	386.7	464.7

* tillers/ft

n = 3

EMS (6df) = 1539

LSD (0.1) = 62.3

(0.05) = 78.4

(0.01) = 118.8

(ii) T otal Sown grass (p $<$ 0.05)

	120 cow days/acre	200 cow days/acre
grazed	265*	233
cut	238	300

$*$ tillers/ft^2

$$n = 3$$
$$\text{EMS(6df)} = 958.8$$
$$\text{LSD(0.1)} = 49.1$$
$$(0.05) = 61.9$$
$$(0.01) = 93.7$$

Appendix 30 : Soil Moisture – Experiment II

(a) Data

Grazed plots

I	K	25 August	8 September	22 September	6 October
1	1	37.6	35.5	35.3	23.7
1	2	36.2	33.0	32.2	22.4
2	1	37.7	34.4	34.8	23.7
2	2	36.7	34.4	33.9	23.4
3	1	39.2	34.5	35.7	24.5
3	2	38.1	34.3	35.6	23.3

Cut plots

I	K	25 August	8 September	22 September	6 October
1	1	39.5	37.3	33.4	22.6
1	2	34.9	30.9	30.7	23.3
2	1	36.6	34.9	34.4	24.7
2	2	37.7	38.2	37.1	27.2
3	1	42.1	39.0	40.6	25.6
3	2	39.1	34.2	35.1	22.5

(b) Analysis of variance

	df	Mean squares			
		25 August	8 September	22 September	6 October
Grazing intensity	1	8.333^+	9.363	7.680	0.608
Grazed v's cut	1	1.163	5.880	1.203	2.001
Interaction	1	0.750	2.253	0.163	0.701
Replicate	2	8.432^+	2.298	14.890	3.076
Rep x Treatment	6	1.828	5.430	4.712	2.045
Total	11	3.503	4.970	6.100	1.975

Appendix 31 : Soil Bulk Density — Experiment II

    (a) Data

(i) Grazed

I	0 — 3 cm	3 — 6 cm	6 — 9 cm	0 — 9 cm
1	0.928*	1.156	1.138	1.026
2	0.898	1.124	1.089	1.031
3	0.886	1.062	1.065	1.005

(ii) Control

1	0.844*	1.144	1.110	1.033
2	0.829	1.095	1.084	1.003
3	0.828	0.986	1.001	0.939

    * gm/cc

    (b) Analysis of variance

Mean squares x 10^2

	df	0–3	3–6	6–9	0–9
Grazing v's control	1	0.046	0.827	0.418	0.182
Replicate	2	0.742*	0.228	0.156	0.126
Replicate x Treatment	2	0.008	0.054	0.044	0.066
Total	5	0.170	0.398	0.216	0.125