A STUDY OF THE DEFOLIATION PATTERN OF SHEEP GRAZING PASTURE

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TABLE OF CONTENTS

Table of Contents (cont'd).

LIST OF TABLES

List of Tables (cont'd).

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Climatically New Zealand is favoured for grass growth and year-round grazing of pastures; this has led to high levels of production per unit area. These have been achieved through manipulation of the factors affecting (i) herbage production of pastures and (ii) the utilisation of this herbage. Enlightened fertiliser useage, drainage, improved pasture species and grazing management have improved pasture production, while improved utilisation has been achieved from progressive changes in management and stocking rate.

With year-round grazing, there is a continuous interaction between the plant and the animal communities. The interaction increases with stocking rate (Arnold, 1968); with increased possibilities of either community being unable to sustain production and collapsing. New Zealand research workers have been aware of the points at which the plant and animal communities interact and in particular the effects of the grazing animal on the plant community (Sears, 1956). The effects of the pasture, in quality and quantity, on the grazing animal appear to be less well understood.

Experiments involving the growth responses of sheep grazing various grass and grass plus clover pastures have indicated the variable nutritive value of pasture species and in particular the high nutritive value of white clover (Trifolium repens L), (Rae, Brougham, Glenday and Butler, 1963; Rae, Brougham and Barton, 1964.)

Australian studies have shown the existence of optimum quantities of available pasture in particular green matter (Willoughby, 1958, 1959) and height of pasture (Arnold, 1964 a) for maximum animal growth rates. Structural changes of the pasture can also affect animal performance mediated through changes in grazing behaviour (Arnold, 1964). These aspects have received less consideration in New Zealand.

The effects of the animals on the pasture are fourfold;

(1) defoliation
(2) treading
(3) excretal return
and (4) seed dispersal.

This last factor is probably of lesser importance in intensively grazed improved pastures.

The treading effect has been studied closely using the technique developed by Edmond (1958). His results indicate the considerable effect treading can have in reducing growth of pastures and changing botanical composition and possible long-term effects brought about by the above and changes in soil properties (Edmond 1966, 1970).

Sears (1948) has shown that the excretal return is an important factor contributing to the high production of New Zealand pastures because of the quantities of nutrients returned in a readily available form. Indications are that with increased stocking rates excretal returns will further favour pasture growth (Barrow, 1968).

The final effect of the animal on the pasture, which is the subject of this thesis, is defoliation. Sears (1956) says "the major influence on pasture growth is the selectivity, intensity and frequency of defoliation and the associated competition for light between species." The defoliation pattern and selectivity of grazing sheep will be discussed in the review of literature.

The frequency and intensity of defoliation of a pasture is likely to vary largely according to the system of grazing management employed. Many systems are possible (Wheeler, 1962; Spedding, 1965) but the most widely used involve either a type of rotational grazing or set stocking.

Under rotational grazing there is some control of the frequency and intensity of defoliation but up until 1965 (Spedding, 1965) nothing could be said definitely for a set stocked system of grazing management. An investigation by Hodgson (1966) in England, involved the frequent observation of small units (tillers) of a perennial ryegrass sward under a set-stocked system of management. He showed that the frequency was proportional to stocking rate and severity increased with stocking rate. A number of similar experiments have been carried out in England and Australia (Arnold and Greenwood, 1968; Morris, 1969; Hodgson and Ollerenshaw, 1969) confirming an increase in frequency of defoliation as stocking rate increases. There is less agreement on the change of severity with stocking rate.

In the investigation reported here, Hodgson's technique was used to estimate the frequency and severity of defoliation of individual tillers in a cocksfoot (*Dactylis glomerata* L) dominant sward under a specific system of grazing.

1. The effect of 2 stocking rates (36.1 and 79.7 sheep/hectare) and
2. The effect of animal breeds (romney and merino).

Experiment 1 was carried out in the autumn of 1970 and Experiment 2 in the winter of 1970.

CHAPTER I. REVIEW OF LITERATURE.

In the review of literature the pattern of defoliation will be examined in 2 sections; first, the observed selectivity of defoliation and secondly, the frequency and severity of defoliation of the pasture and its components. A short introduction will give a background to, the factors leading to grazing by animals, grazing behaviour, and the grazing process. In general discussion will be confined to the pattern of defoliation produced by sheep.

Animal Intake and Selectivity

The action of eating by the animal arises from the animal's drive to satisfy its appetite and is modified by a number of factors. McClymont (1967) has suggested a model to explain how eating of phagic behaviour is controlled. Phagic behaviour is stimulated by an inherent energy demand of the animal the magnitude being proportional to the metabolic size of the animal (body weight to the power of 0.75 approx.). However other facilitatory or inhibitory stimuli may arise which cause the animal to continue or cease from phagic behaviour. These stimuli may be inherent e.g. ~~maximum~~ energy intake, distension of stomach, fatigue (all inhibitory) or adventitious e.g. heat, disease, social inhibition and psychic stress, unpalatability, nutritional stress (nutrient deficiency or excess).

The selection pattern of the animal in the pasture is mediated by stimuli acting through either the smell, sight, taste or touch senses. The response of the animal to these stimuli may be either innate (determined at birth) or learned. McClymont suggests that innate behaviour probably occurs only in very young animals. The known learned responses are from (1) dam,

(2) habit - what type of pasture the animal was reared on,

(3) avoidance of plants producing rapid intoxication, and

(4) habituation - reduction in intake due to continual exposure to one fodder, e.g. roughage in spring.

Besides the affect on selection, these internal animal factors along with pasture factors will effect the grazing behaviour of the animal.

Grazing Behaviour:

The nutrition of the grazing animal is dependent upon the animal's ability to gather its own diet and the quality of that diet. Arnold (1963) has described the grazing behaviour of sheep: "On good pasture (yielding about 2,000 lbs dry matter per acre) sheep will graze for 8 hours a day. This grazing time is usually made up of two or three long periods of grazing interspersed by much shorter periods." The rate of eating is probably about 40-60 bites per minute (Arnold, 1964a).

Studies with sheep have shown that grazing behaviour varies with physiological state and changing pasture conditions. The appetite of the animal increases with age, lactation, poor previous nutrition and after shearing and this is reflected in either greater rates of eating or duration of grazing or both (Arnold, 1963; Arnold and Dudzinski, 1967, 1969; McManus, Arnold and Ball, 1967). British breeds of sheep have a greater intake than merinos (Arnold and Dudzinski, 1969) but it is not known if this causes a significant change in grazing behaviour.

Grazing behaviour is strongly influenced by pasture factors. With a decrease in availability Arnold (1963) found that the eating rate first increased to a maximum at about 100 bites per minute and then the grazing time increases, up to a maximum of about 10.3 hours. These changes represent the animal's flexibility to satisfy its appetite because of a reduced size of bite occuring as the availability declines.

Recent studies indicate the reduced height of the pasture as probably the important factor causing this reduced size of bite and concurrent grazing behavioural changes. Allden and Whittaker (1970) disturbed the usual relationship between availability and pasture height (by rotary hoeing strips through plots reducing availability but maintaining height) and found that the rate of intake was closely related to plant height, there being little relation with herbage yield. They found that the size of bite increased almost linearly with length, whereas after a small initial increase the rate of biting decreased. (See Fig. I1). At greater tiller lengths ($>$ about 10cms) the size of bite and rate of biting varied inversely to maintain a constant rate of intake. Partial compensation for reduced intake was also achieved by an increase in grazing time. It is important to note that each of these adaptations (grazing time and rate of biting) reaches a limit. This means that they become increasingly less effective in compensating for a reduced intake, in particular where the animal requirements are high e.g. lactation (Arnold and Dudzinski, 1969).

At low pasture availabilities (height) Allden and Whittaker found that young animals (lambs) were able to maintain a greater intake than older animals (yearlings) which they suggested was due to the relative mouth sizes; a small mouth giving an advantage under such conditions. However at high availabilities the situation is probably reversed.

Increased grazing time due to reduced size of bite may not occur as a result of reduced availability alone. Arnold (1963, 1964) has suggested that where an animal is forced to graze selectively e.g. where preferred green leaf is enclosed in dead and dry material, grazing time increases.

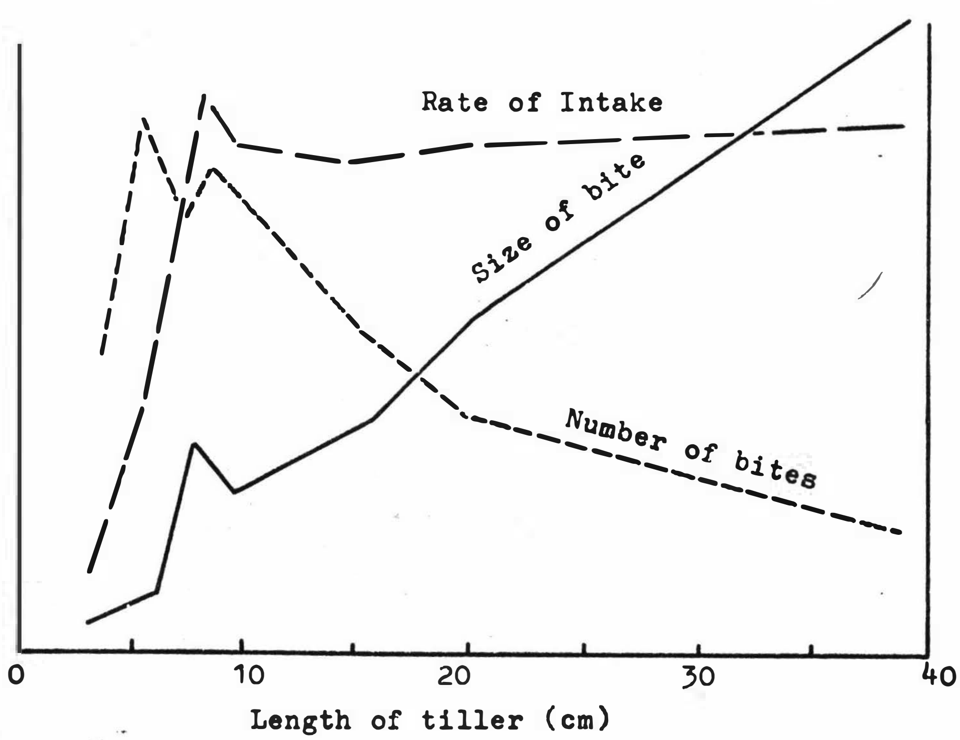

Fig I.1. Relation of rate of herbage intake, rate of biting and size of bite to length of tiller.
(After Allden and Whittaker 1970. Fig 3).

The Grazing Process:

The grazing process for sheep has been defined by Arnold (1960) as eating off in a horizontal direction and selection in a vertical direction. This grazing off in a horizontal direction means that it is rare for sheep to graze from the bottom of a pasture upwards in the sense of biting whole grass or clover leaves off at their base. Rather than eating a favoured area from 6" to ground level at once the area gradually becomes more tightly grazed (Arnold, 1964). This pattern necessitates the removal of leaf tips first.

The development of patches under conditions of undergrazing (e.g. Norman, 1957; Suckling, 1964) confirm this horizontal process. As the surrounding vegetation grows more rank and unpalatable the grazed patches will be more and more closely defoliated.

The second part of the process involves selectivity in a vertical plane. For example in a lucerne stand (Medicago sativa L) containing a mixture of tall, medium and short plants and grazed with romney wethers for 24 hours the animals concentrated their grazing on the leaves and stems of the medium plants and avoided the more mature leaves and stems of the tall plants. The short plants were relatively ungrazed in the limited grazing period allowed (Watkin 1969 pers. comm). In other words there was a definite selection for the young leaf and stem material and against the more mature plant material.

THE PATTERN OF DEFOLIATION:

A. Selectivity.

The selectivity of the grazing animal has been studied both by examining the pasture before and after grazing (Cockayne, 1919; Stapleton 1927; Reid, 1951; Milton 1953; Norman 1957 and others), by sequential photographs of fixed quadrats in grazed pastures (Willoughby, 1965; Arnold and Greenwood, 1968) by an examination of the diet of the animal (Weir and Torell, 1959; Taylor and Deriaz, 1963; Hercus, 1960). The former techniques give the most readily interpretable information for the effect of grazing on the pasture and the latter are more useful in terms of the nutritive value or quality for the grazing animals. The selectivity in relation to nutritive value and quality usually results in a diet of greater digestibility, nitrogen, phosphorus and total digestible nutrients contents and less soluble carbohydrate and crude fibre (Arnold, 1960; Blaser et al, 1960; Meyer, Lofgreen and Hull, 1957, Weir and Torell, 1959). However as these aspects are of less agronomic significance than the selectivity of different components of the pasture e.g. species or parts of individual plants (leaves, stems etc) that affect the continual growth and productivity of the pasture they will not be discussed further.

Within a plant community the grazing animal is faced with several components which vary according to the stage of growth, either leaf, leaf sheath or stem, and seed head. Both sheep and cattle select leaf in preference to stem when grazing lucerne (Arnold, 1960; Meyer et al, 1957). With grass species the same pattern has been shown for *phalaris* spp., ryegrass (*Lolium* spp) and mixed species swards (Arnold, 1960; Stapleton et al, 1927; Milton, 1953; Spedding, Large and Kydd, 1966).

In most improved, closely grazed pastures where a grass species is the dominant component, leaves are produced at or near ground level and stem is only a very small proportion of that material available over the year. The ability to select between different types of leaves will be more important. Hodgson (1966, 1969) showed, for a closely grazed perennial ryegrass (*L. perenne* L.) sward, that the youngest leaves on grazed tillers were defoliated more frequently than the older leaves. Two similar studies for cocksfoot (Morris, 1969) and *Lolium rigidum* (Arnold and Greenwood, 1968) have shown the preferential selection of expanding and newly mature leaves rather than old or defoliated leaves. Arnold (1960) found no such preference between young and old leaves in the spring but at a more advanced stage of maturity there was a definite selection of young leaves, then mature leaves and finally stem for merino wethers grazing lucerne. The selectivity was greater the more mature the herbage. This tendency to graze the youngest, most actively growing leaves may be explained as the result of deliberate selection by the sheep (Arnold, 1966) or simply that the youngest leaves are more accessible (Hodgson, 1966; Morris, 1969).

It has often been observed that grazing animals select against dead material in a pasture. On mixed swards grazed over the winter and spring periods in Wales, green material was preferred to winter burnt and discoloured leaves (Stapleton et al 1927; Milton, 1933, 19̣3). Cattle also avoid eating dead material (Cowlishaw and Alder, 1960, 1967; Corbett, 1957). The presence of dead or dry material in the pasture also influences the selection among the components available e.g. leaf, steam etc. When pastures are mainly green the diet is selected almost exclusively among the green components (Arnold, 1964). On a phalaris dominant pasture, when the dry matter content was high, at about 50%, sheep selected a diet comprising 70% green components. These results were determined using the oesophogeal fistula examination technique. As a result there was almost complete suppression of preferences amongst the green components (Arnold, 1964). But the failure to select between green components when dead matter content of pastures is high may not always apply; the selectivity pattern for youngest leaves observed by Hodgson (1966) was for pastures of about 60-70% dead material (dry matter percentage), and in the presence of a considerable quantity of older green leaves.

In a complex pasture there is opportunity for selection between species. The selection of one species against another may depend either on its palatability (causing facilitatory sight, smell, taste or touch sensations) or accessibility. Many palatability trials have been carried out involving either small units of pure swards in which the animals had access to a variety of species at one time, or where the animal was placed on a certain area for a set period of time - usually 24 hours (Stapleton et al 1927). The method of assessment was the same in each case. Before grazing, the sward was given a score on an appropriate scale according to the quantity of material present and similarly after the grazing period. The value for the percentage of the species removed was the palatability rating for the species. Timothy, (Phleum pratense L) ryegrass species, white clover and cocksfoot were found to have high relative palatabilities and fescue (Festuca spp) and phalaris low ratings. Similar results have been found in later trials (Ivins 1952). Under pasture conditions the high relative palatability of white and red clover (Trifolium protense L) compared to grasses has been noted (Voisin, 1959; Stapleton et al, 1927; Milton, 1933). On summer and autumn hill country pastures in Wales, that were mainly green, sheep selected grasses in preference to a variety of herbs (Milton, 1953).

Many instances have been given where changes in pastures, mainly through changes in botanical composition, have been ascribed to the pattern of selection among different species (Stern, 1968; Suckling, 1964; Levy, 1955; Sears, 1956 and many others). However the following trial is an illustration of what changes can be effected. In a detailed trial involving both cattle and sheep under continuous and rotational grazing, Norman (1957) found selective grazing to alter the botanical composition of a downland permanent pasture. The initial composition involved mainly creeping bent, (Agrostis stolonifera L), red fescue (Festuca rubra L), ox-eye daisy (Chrysanthemum leucanthemum) and bulbous buttercup (Ranunculus bulbosus). The selection pattern for these was determined by examining open and closed quadrats of individual species before and after grazing. Under close sheep grazing, red fescue and creeping bent dominated the pastures due to poor palatability of both species even though accessible at all times. Under cattle grazing there was an increase in the weed species ribwort plantain (Plantago lanceolata) and bulbous buttercup (Ranunculus bulbosus). The differences between the management systems were not of very great size.

Palatability appears to vary with many factors but many so-called unpalatable species are more palatable in the spring during the phase of most active growth. This factor may help to explain the selection of young leaves rather than old leaves as they are likely to be growing more actively. In a pasture of species with diverse structure, accessibility is likely to be an important factor in selection pattern. Uneven canopies, which are more marked the greater the availability or the more mature the herbage, would provide variation in accessibility. On relatively uniform closely grazed swards Hodgson (1966) and others (Morris, 1969; Hodgson and Ollerenshaw, 1969) have found that at any single grazing the average green leaf length of the grazed tillers was greater than that of the ungrazed. The sheep may be selecting such tillers because of greater accessibility or because they are more easily removed. The measure of green leaf length (G.L.L.) does not give an accurate indication of the weight and size of a tiller because of a great variation in the thickness of tillers. Hodgson (1966) mentions that in some cases G.L.L. was estimated as that of the main tiller plus the length of leaf of secondary tillers.

The selectivity pattern is modified by a variety of animal, pasture, management and other factors.

1. Animal Factors.

The animal species involved is an important factor in selective grazing. When offered a choice of pasture types goats and sheep were less and swine were more discriminating than cattle and horses for a wide number of herbage species as single plants and mixtures (Hardison et al 1954). Beruldsen and Morgan (1938) also found sheep to discriminate less than horses and cattle. The physical ability to select may also vary. Stapleton (1948) suggests;

"The sheep is more refined in its ability to select than the bovine, the sheep can with ease take an individual plant or an individual leaf, the bovine selects patches, the sheep both individual plants and patches."

In an investigation involving sheep and steers grazing lucerne, the sheep left less leaf on the plants after grazing even though the steers removed a greater amount of dry matter (Meyer et al, 1957). The relative sizes of the mouth parts probably would enable sheep to graze more precisely than cattle.

The selective grazing of cattle associated with dung patches is well known. In one instance nearly 100% of grass and grass-legume forage growing near dung was at least partially rejected and 81% was completely rejected after 3-4 weeks (Marten and Donker, 1964). This rejection appears to be due to the smell of the faeces (MacDiarmid, 1969), and may persist for up to 4 months depending on the rate of disappearance of the dung patches. No similar observations have been reported for sheep.

Breed differences in sheep do not appear to be important under intensively grazed conditions. However Arnold and Dudzinski (1969) have indicated that differences in intake exist between British breeds and merinos when grazing very short herbage. It is possible that selectivity is affected through grazing behaviour adaptations. For hill country or native pastures differences may be more apparent. Hunter (1960) has suggested that the cheviot breed adapts better to grazing low fertility areas, whereas the scottish blackface grazed more uniform and fertile pastures. The reasons for this are probably complex with some genetic influence possible. Amongst cattle it is suggested that tropical breeds may graze more selectively than British breeds (Joblin, 1962). The author suggests the grazing process is more closely akin to "the biting action of sheep than the tongue grazing of cattle from temperate climates".

The high selectivity of young animals grazing pasture is frequently noted. Lambs high stocked on a phalaris - annual grasses - subterranean clover pasture only grazed 33% of the paddock over the winter season in an Australian trial (Arnold, 1964b). Blackmore (pers. comm 1968) has also noted a very marked patch effect in lamb grazed pastures, resulting from continuous selection of particular areas of the paddock. Under such conditions the ungrazed areas become increasingly rank and unacceptable. This characteristic is utilised in some creep grazing systems adopted (See Large and Taylor, 1956). This pattern exhibited by young animals may disappear after a short time (Hodge and Doyle, 1967). Examining oesophogeal fistula samples taken from lambs and yearling merino sheep on the same pasture, these workers found no differences in nitrogen content and botanical composition of diet. Both groups increasingly selected clovers against grass in perennial pastures over the spring period even though the proportion of clover in the pasture was declining. Other investigations suggest that there is little difference between yearling and adult sheep (Arnold, 1964a).

No differences have been found in the diets selected by ewes in different physiological states when grazing phalaris - annual grasses - subterranean clover (T. Subterraneum L.) pastures over a range of availabilities (McManus, Arnold and Ball, 1968).

2. Pasture Factors.

It has been said that the degree of selective grazing is directly related to the availability of pasture (Greenhalgh, 1966). The greater the availability, the greater the degree of selection. On a grazed stand of lucerne Arnold (1960) found that the rate of decline in leaf percentage was faster the greater the quantity of material present.

Under pasture conditions it is probably the availability per animal as well as per acre that leads to selective grazing. It has frequently been observed that under low stocking rates pastures tend to be grazed in a patchy manner (Suckling, 1964; Norman, 1957; Hodgson and Ollerenshaw, 1969). Examining the diet of grazing merino sheep Arnold et al (1966) found the greatest differences between the diet selected and the average of the pasture available was during the season of greatest availability. The converse situation where an inadequacy of pasture is available probably restricts selectivity so that components are consumed in proportion to their availability (Willoughby, 1959). The greater degree of selection at greater availability per unit area or per animal may arise from the greater natural variation in the pasture and the greater opportunity to select. This variation also arises as the forage moves into a more advanced stage of maturity which is what often occurs as availability increases.

Often an increase in availability of pasture is accompanied by a marked change in structure. Usually the canopy will be taller and it has been noted that in taller swards there is a greater emphasis on selection of younger tillers during grazing (Moore and Biddiscombe, 1964). The change in structure is particularly marked in the Australian phalaris - annual grasses - subterranean clover pasture during the summer dry period. The clover forms a layer close to the ground below any green shorts with dry grass forming an enveloping web over the desired components. The most readily accessible component to the animal is the dry grass. In an examination of oesophogeal fistula samples for the diet selected by sheep grazing a pasture of this type clover and some of the green material was not selected until some of the dry grass had been eaten (Arnold, 1964). Under such pasture conditions the grazing process has to be selection on a vertical plane.

Selectivity may be greatly affected by the growth form of the pasture species. In examining the pattern of defoliation in a pasture of morphologically diverse species the grazing of red fescue and cocksfoot has been attributed to their uprightness (Norman, 1957). The ingress and persistence of species of poa, in particular *Poa trivialis* into pastures is suggested to be due to their ability to resist grazing (Kydd, 1966). Because tiller density is higher than that of many species, for any given availability a greater proportion of dry matter will be close to ground level. Therefore at a defoliation a lower proportion of the leaf of such plants can be easily grazed. Also a large proportion of these Poa spp tillers are prostrate. The implications of growth form on botanical composition and maintained plant vigour under selective grazing are discussed by Norman (1960). Upright species and those of greatest relative palatability will be grazed more severely and are less likely to persist in a pasture, whereas those of a more prostrate growth form and least relative palatability will be less severely grazed and so persist.

Mulcahy (1962) has examined the pattern of selection in two pasture types; a phalaris-lucerne pasture and a cocksfoot-white clover pasture in the vegetative stage of growth. These were grazed at 100 sheep per acre for 8 days and differences in the composition was determined at 2 day intervals using the point quadrat technique. In both swards the legumes were selected in preference to the grasses but as the availability declined, there was a faster rate of decline in the grass species contribution. On both swards the top of the pasture was grazed first. This study showed no differences in the pattern of defoliation and selection of two simple grass legume pastures at similar stages of maturity. However at a later stage of maturity it might be expected the sheep would graze different pasture types in a different manner, as the pasture factors already mentioned come into effect. The study does confirm that clovers are preferred to grasses but also indicates that the species preference may alter during the grazing period. The seasonal acceptability of species also alters depending on growth rate and other factors (Arnold, 1966).

3. Management Factors.

The adoption of rotational grazing techniques, particularly under close grazing, largely removes selective grazing. As the animal has a shorter time on the pasture there is less opportunity for selection and since at any one grazing the proportion of material removed from the pasture is, or can be, greater depending on stocking rate, all components are more likely to be grazed with equal severity.

Under set-stocking conditions the main variable that could affect the defoliation pattern is stocking rate. As has been discussed this can be indirect through resultant changes in the pasture factors, e.g. structure. The direct effects of stocking do not appear to be great. On a Mitchell grass association, increasing the stocking rate from 1 sheep per 4 hectares to 1 sheep per 2 hectares did not alter the order of preferences of individual species chosen but the speed of progress from one to the other was greater (Weston and Moir, 1970). The selection of young leaves against older leaves and the tallest available tillers at any one defoliation was similar for stocking rates of 29, 77 and 91 sheep per hectare (Hodgson and Ollerenshaw, 1969).

Harvey (1962) examined the pattern of selection at 3 stocking rates of 40, 100 and 200 sheep /acre (102, 255, 510 /hectare) on a phalaris-white clover and perennial rye-grass pasture. At the highest stocking rate the selective ability of the sheep was greater in the horizontal direction; the pastures which were 2-3" high at the beginning of the experiment had greater amounts of total material removed in the 0-1" region than the 1-2" region by the 200 sheep/acre treatment. There were no differences in the botanical composition of the diet selected. It would be expected that if the amount of material per animal became reduced as under high stocking rates that the animals would remove a greater proportion of the material close to the ground level.

4. Other Factors.

Climate may have an effect on the selectivity pattern of grazing sheep. Tribe (1950) has described how sheep on hill areas will stay in the bottoms in "rough" weather but in fine weather go to the hill tops. The associations in these areas will be grazed as a consequence. In wet weather the rank vegetation is avoided but during dry spells there is greater attention to bogs and any plants of high water content.

B. Frequency and Severity of Defoliation of Individual Units.

The major effect of the animal on the growth of the pasture is through the frequency and severity of defoliation of the individual growth units. Many cutting trials have shown how the effect on growth varies according to the pasture species, season of the year and the particular frequency and intensity adopted. (Brougham, 1960; Davidson, 1968).

Frequency of Defoliation.

The frequency of defoliation or the interval between successive grazings can be determined by the system of management. Under a system of rotational grazing it is clearly possible to impose any number of defoliations per season or year. However the frequency of defoliation may be confounded depending on the length of time that the animals are allowed to remain grazing the pasture. If animals are allowed too long a grazing period individual tillers may be grazed on one or more occasions. Voison (1959) suggests that 4-6 days is a maximum period for grazing before cattle will start to graze tillers a second time.

Under a system of set-stocking no such control of frequency is possible because the relationship between the various animal and pasture factors with the frequency of defoliation of individual tillers are less well known. It has been suggested that individual plants are rarely defoliated frequently (Wheeler, 1962), but also that the opposite may occur (Spedding, 1965). Spedding (1965b) attempted to compare what differences may occur between the two systems of management and suggested that it was not so certain that set-stocking necessarily results in a very different pattern of defoliation, "It is most unlikely that in a set-stocked area each plant is defoliated daily: the actual frequency and severity must vary with stocking rate and many other factors, but these interactions have not been investigated."

In 1966 Hodgson published the results of an investigation of the frequency of defoliation of individual tillers in a ryegrass pasture set-stocked with yearling masham sheep at 2 stocking rates of 19 and 30 sheep per acre (48.5 and 76.5 /hectare). 500 tillers were marked in each paddock (⅗ acre) and these were examined every 3 - 4 days and recorded as either grazed or not grazed and also for the length of green leaf per tiller present. The results showed that on the medium treatment (19 sheep/acre) the tillers were defoliated on average every 11-14 days and on the high treatment (30 sheep/acre), every 8-11 days. The authors suggested that these figures may have underestimated the frequency due to the short period of observation, and to some defoliations being so severe that no more leaf was produced on that tiller. Since this study the pattern of intermittent defoliation of small units of herbage in a set-stocked sward has been confirmed (Morris, 1969; Arnold and Greenwood, 1968; Hodgson and Ollerenshaw, 1969; CSIRO Report, 1965). Therefore although the set-stocked pasture is grazed continuously, individual parts are rotationally grazed.

The frequency of defoliation of individual units has been found to vary considerably. Lambs grazing a cocksfoot pasture maintained at 3 different levels of leaf area index (LAI), approx. 3, 4, 5 defoliated small units (8 x 8 cm) every 19, 24 and 36 days respectively. The stocking rate was similar for all treatments at about 22.5 lambs per hectare. A CSIRO estimate (1965) reports a unit (unspecified) was defoliated every 21 days when grazed by mature ewes at 17 sheep/hectare. These estimates indicate that under set-stocked conditions individual units are not defoliated frequently under medium levels of stocking. However there is an increase in frequency with stocking rate and at high levels of stocking (91 sheep/hectare), individual tillers may be defoliated more frequently than once per week (Hodgson and Ollerenshaw, 1969).

These data confirm the proposals made by Spedding (1965b) that stocking rate is a major factor affecting the frequency of defoliation but the increase in frequency from the data (Table 1) do not indicate that the increase is directly proportional to stocking rate as has been concluded from Hodgson's original experiments (Arnold and Greenwood, 1968).

Severity of Defoliation

One of the difficulties in the determination of severity of defoliation is choosing a suitable criteria. In cutting trials the severity of defoliation, or intensity as is used synonymously, has been used to refer to either the reduction in height of a pasture or merely the height to which the pasture is reduced regardless of initial height (Brougham, 1959). Arnold and Greenwood (1968) have suggested that the severity of defoliation refers to the proportion of available material removed in a given time (i.e. at a defoliation). The criteria adopted in the examination of the severity of defoliation of individual tillers in a grazed sward has been the determining of the proportion of leaf length (either green or total) removed at a single defoliation; calculated from the difference in leaf length of a tiller between successive defoliations with a correction for the estimated increase in length due to growth over the same time interval.

Table 1.1. A comparison of the severity of defoliation with the stocking rate (sheep/acre) and the grazing pressure (sheep/100 Kgms total dry matter).

	Recorded value			Ratio (A = 100)		
	Paddock					
	A	B	C			
Severity of defoliation						
mm/defoliation	30.8	49.1	52.9	100	159	172
%/defoliation	13.4	38.0	67.2	100	284	501
Stocking rate (sheep/hectare)	29	77	91	100	266	314
Grazing pressure	10.1	28.2	48.8	100	278	483

(Modified after Hodgson and Ollerenshaw, 1969, Table 15 P.233)

Hodgson and Ollerenshaw (1969 - See Table 1.1) found that with an increase in stocking rate from 29, to 77 to 91 sheep/hectare that the severity of defoliation increased for 13.4, to 38.0 to 67.2%. In his study at different L.A.I. Morris determined the severity of defoliation as about 24%, with no significant differences between L.A.I. treatments even though the severity under the low treatment (L.A.I. = 3) was 50% greater than that of the high treatment (L.A.I. = 5). Estimates of the grazing pressure (the number of animals per unit of dry matter available) indicate that the increase in the severity of defoliation may be more closely related to the grazing pressure than to the stocking rate (See Table 1.1). This indicates that the severity of defoliation may also be related to the pasture. Under the high stocking rates the amount of pasture present per unit area was less and consequently tillers were initially shorter. As the stocking rate increased there was a greater absolute length of green leaf removed which when expressed as a percentage of the initial tiller leaf length gives a much greater rate of increase in the severity of defoliation with stocking because of the initially shorter tillers.

Willoughby (1958) has suggested that under reduced availability the grazing animal compensates for lower rates of intake by a behavioural change, an increase in grazing time and by biting closer to the ground level. The closeness to ground level that an animal can and will graze may be as important in plant recovery from grazing as the proportion of green leaf removed. Severe grazing can severely decrease growth rate due to removal of cells that are capable of further expansion as well as those capable of production (Davidson, 1969). Higher stocking rates were certainly accompanied by more closely grazed pastures in the above experiments by Hodgson et al., however they were probably not grazed hard enough to effect the actively dividing and "reserve" regions at the leaf bases. Wheeler (1962) suggested sheep can only graze to within an inch or two of the ground. Scoffield (1970) has found for romney wethers grazing a clover pasture under very severe conditions of low availability (200 kgs DM/hectare) that stolons on and even below ground were uprooted and grazed. This would suggest that if an animal is forced to it can probably graze pasture plants so severely as to cause plant death.

Factors affecting the frequency and intensity of defoliation.

1. Animal Factors.

No experiments have been sighted which examined differences in frequency and severity of defoliation between animals of different ages, sex, physiological state or breed. Presumably a difference in intake by animals would be reflected in a difference in the frequency and severity of defoliation of similar pastures.

2. Pasture Factors.

As indicated the severity of defoliation is probably related to the quantity of material available and will therefore probably increase with shorter pastures. The frequency of defoliation also increased as the pasture decreased in availability (Hodgson and Ollerenshaw, 1969). Arnold and Greenwood (1968) found that for merino wethers grazing an emerging annual pasture of Lolium rigidum fewer marked plants were grazed in the second than the first week of observations even though over this initial period there was a decline in the quantity of dry matter present on the pasture to a low level of about 50 kgs DM per hectare. There was a continual fall in frequency as the pasture increased in quantity during the following 6 weeks. The fall during the second week may have been due to difficulty in prehending such short shoots present at that time. The fall in frequency in the succeeding 6 weeks is a natural result of an increasing quantity of total D.M. present due to an increased size of existing tillers and the development of new tillers allowing the appetite to be satisfied from a smaller number of tillers or area of ground.

In the same experiment the authors indicate the growth rate of the pasture may be important in altering the intensity of defoliation. Determining the intensity of defoliation as the proportion of material removed per week they found a rapid decline from 14 to 6% in the first 3 weeks. Thereafter the decline was steady until the seventh week when there was a sharp rise in the % removed. The authors suggest that this rise was due to a fall in the growth rate of the pasture resulting from a nitrogen deficiency and suggest that a similar response may occur in other grazing situations. Different seasons may give similar results due to the changing growth rates.

No differences in defoliation pattern have been shown due to the structure or botanical composition of a pasture. The experiments described have all been conducted in single species swards. Where differences in morphology occur between species in a pasture it would be expected that the more upright species would have a greater proportion of material removed at a grazing (Norman, 1960). Palatability, stage of growth etc. of the different species may also be expected to give rise to differences in the frequency and intensity of defoliation through selective grazing as described. Tiller number is unlikely to be important unless it varies independently of the total dry matter. As tiller number declined or rose and total dry matter remained constant the frequency of defoliation may vary similarly. An increase in tiller number may be accompanied by a decrease in the intensity of defoliation due to greater proportion of plant material being closer to ground level and therefore not easily removed by the grazing animal (Kydd, 1966).

Chapter II. EXPERIMENT I

A. Introduction.

The object of this experiment was to examine the frequency and intensity of defoliation of individual tillers under medium and high stocking rates and their changes under conditions of changing height and availability of pasture.

The experiment was carried out in the Autumn when tillering was vigorous and thereby enabled a study of the effect of different aged tillers on the pattern of defoliation.

B. Materials.

Location of Experiment.

The experiment was set up at the "Tuapaka" Agronomy research area of Massey University. It is situated 13 kilometres north-east from Palmerston North on a Tokomaru silt loam at the wet end (Pollok 1971 pers comm.) at an altitude of 70 metres A.S.L. and at latitude 40° 21'S.

Temperature and rainfall records, presented in Appendix I have been taken from the D.S.I.R. weather station 13 kilometres away.

The "Tuapaka" research area was fenced to give paddocks of about 0.27 hectares, which for the last 3 years had been used for a stocking rate x pasture species x animal species trial. Records had been taken of various pasture and animal parameters.

Layout of Experiment.

Two plots, sown to N.Z. Grasslands "Apanui" cocksfoot (*Dactylis glomerata* L) in 1966 as part of the trial mentioned above, were used for this trial. Each plot was divided to give two sub-plots of 0.18 hectares and 0.09 hectares representing a medium and high stocking rate (hereafter called medium and high treatments) respectively and giving 2 replicates per treatment.

Experimental Animals.

On March 31st 1970, 28 mature romney ewes were ranked according to weight. 7 animals were allocated to a plot to give a similar liveweight distribution and mean for each plot. The mean stocking rates during the trial were 36.1 and 79.7 sheep per hectare on the medium and high treatments. The numbers of animals on each plot varied slightly over the experimental period (See Table II.1) as adjustments were made to keep the replicates similar in quantities of pasture present. Period I (March 31st to April 23rd) and Period II (April 23rd to May 14th) represent an arbitrary division of the total experimental period into approximately similar periods of 3 weeks to aid comparisons of changes in the pattern of defoliation with time and with decreasing height and availability of pasture. The use of short periods of observation has been discussed by Hodgson (1966), who found that for shorter periods (15 days as against 30 days) the frequency of defoliation tends to be slightly less than the longer periods. He suggests that edge errors of the short period may lead to slight underestimations of the frequency of defoliation.

Prior to the trial the sheep were grazed on cocksfoot pastures similar to the experimental sward for 5-6 days.

Table II 1. Stocking rates.

	Medium		High	
	Sheep/plot	Sheep/hectare	Sheep/plot	Sheep/hectare
Period I (31 March - 23 April)	7.6	41.6	7.4	81.2
Period II (23 April - 14 May)	5.6	30.7	7.0	76.9
Period I & II (31 March - 14 May)	6.6	36.1	7.3	79.7

C. Methods.

Pasture Management.

On February 28th the plots were closely mown, after being grazed over the late summer period, to remove as much dead material as possible. Because of a drought period over the previous spring and summer, growth was negligible until the autumn rains commenced in mid-March. From then on growth was rapid and the experiment commenced on 31st March at which time the plots contained about 1250 kilograms of dry matter per acre. The height of the pasture was 6 to 10 cm.

For 3 years previous to the experiment the plots had received an annual application of 500-600 kilograms of urea per hectare in 3 dressings, applied in August, November and March. On March 9th, 1970, 125 kilograms of urea was applied.

Tiller Identification.

Two hundred tillers in each plot were identified by slipping loops of plastic coated wire over them and down into the base of the sward, anchoring the loops to the ground. These were located 20 to each of 10 transects, 7.5 metres long. The loops were about 10 mm in diameter, made from 0.5 mm copper wire with a plastic coating 0.25 mm thick (Plate 1).

The transects were positioned by dividing each plot into five equal areas and randomly selecting a site in each area, at each site a pair of transects was located. The ends of each transect were marked by 40-50 c.m. lengths of "conduit" pipe driven into the ground with only 4-5 c.m. appearing above ground. The transect line, a plastic coated clothes line marked at 30 c.m. intervals, was placed in position at each observation by permanently attached iron pins which fitted into the "conduit" pipes. The position of the "conduit" pipes was marked with white wooden pegs.

Because of difficulty found in locating tillers marked singly it was decided to mark tillers in groups of 4. Within each group tillers were systematically marked with red, white, blue and orange markers. These colours were used to aid relocation and also to mark different age categories of tillers. Red, white and blue markers were on tillers of greater than two leaves at the time of marking and classified as "old" tillers and orange loops marked tillers of two leaves at the time of marking and classified as "young" tillers. At the time of marking mature tillers had from 3-5 green leaves, so that newly developed tillers were marked as those having not more than two leaves. Tillers of one leaf were not marked in this category because they were often of very small size in relation to the greater proportion of the tiller population. After three weeks (at the commencement of Period II) a further "young" tiller selected by the same criteria, was marked in each clump using a yellow loop. These were classified as "youngest" tillers. Tillers within a group were 4-7 c.m. apart and clumps were never closer than 20 c.ms.

Measurements.

(a) Individual tiller records.

At 2-4 day intervals (See Appendix II Table 1) all tillers were examined and recorded as either grazed or not grazed. When tillers were grazed the particular leaf grazed was recorded; the

Plate 1.

View of plots showing transect in position (upper) and grouped markers beneath the transect line (lower).

youngest at each observation -1, next youngest -2, and so on. Freshly grazed leaves were split with a needle to give a slit 3-5mm long parallel to the leaf veins and running to the freshly severed edge. The presence or absence of this slit at succeeding observations showed whether the leaf had or had not been grazed. This method proved suitable giving agreement with green leaf length measurements.

Within each plot 3 transects were randomly selected and at each observation all tillers besides being recorded for defoliation were measured for height, and for length of green leaf present. The length of each leaf was taken as that from the tip to ground level. This assumes that cocksfoot leaves are attached at or near the ground surface in vegetative plants (See Morris, 1969).

(b) Pasture Measurements.

(i) Availability and Growth Rate:

At weekly intervals samples 1.3 x 0.3 metres were cut to ground level from each plot (6 from low treatment and 4 from high treatment plots) using a portable "Sunbeam" shearing handpiece. Each sample was weighed green and then bulked within plots. A 40-50 gm sub-sample was taken, weighed and dried at 80°C for 24 hours in a "Unitherm" electric oven, and reweighed for dry matter determinations. On 4 occasions 50 grams subsamples were taken and subdivided for botanical composition into green cocksfoot, other species and dead material. These were weighed after drying.

Growth rate was determined by the Australian difference method (described by Lynch, 1966). Within each plot two 1.8 x 0.9 metre cages were placed on selected area, judged as representative of the plot. After 2 weeks these were cut to ground level and the samples dried and weighed. The growth rate was calculated as the difference between the caged samples and the availability at the time of placement of the cages. The cages were then placed at different sites and the procedure repeated.

(ii) Pasture Heights:

On three occasions the average height of the pasture over each group of tillers was recorded. Each record was taken from the mean of 2 estimates per clump, determined using a ruler standing on the ground.

(iii) Tiller Density:

On three occasions 50 tiller cores were taken from each paddock and disected in the laboratory to determine the tiller densities. These cores were taken with a 5 c.m. diameter tiller core sampler of the type described by Mitchell and Glenday (1958). The tillers were categorised as cocksfoot, other species and dead.

(c) Animals records.

(i) Liveweight:

Following initial weighings sheep were weighed on two further occasions using "Avery" portable scales.

(ii) Grazing Times:

Three sheep in each treatment were fitted with "Kienzle" vibrarecorders (described by Allden, 1962) to determine the daily duration of grazing. After 3 weeks the recorders were changed to different sheep to avoid undue irritation from the harnesses.

Analysis and Presentation of Results.

The analysis of variance for the frequency of defoliation was for a split-split-plot design. The 2 sites were main plots with subplots of the 10 transects within each mainplot x treatment. Further subplots were then taken for the 2 periods within each transect. This experimental design has the advantage of increasing the accuracy of determining differences in the sub-plot and sub-sub-plot treatments. At the same time some accuracy is lost in the main plot treatment, which in this case was stocking rates. The experiment therefore ensures a high level of accuracy when comparing differences between period I and period II, which represents differences in pasture height and availability. Less data is available on the pattern of defoliation in relation to pasture height effects than in relation to stocking rate effects.

General pasture records, animal measurements and tiller analysis results are presented in a summarised form in figures and tables with standard errors for tabulated values. The data from which they have been derived are shown in Appendix II.

D. Results.

Pasture Measurements.

(i) Availability:

An estimate of the changing quantity of total dry herbage available at each stocking rate is presented in Fig. II.1 (curves drawn free hand). Towards the end of the experiment some difficulty was experienced in sampling accurately owing to soil contamination.

Figure II. 1.

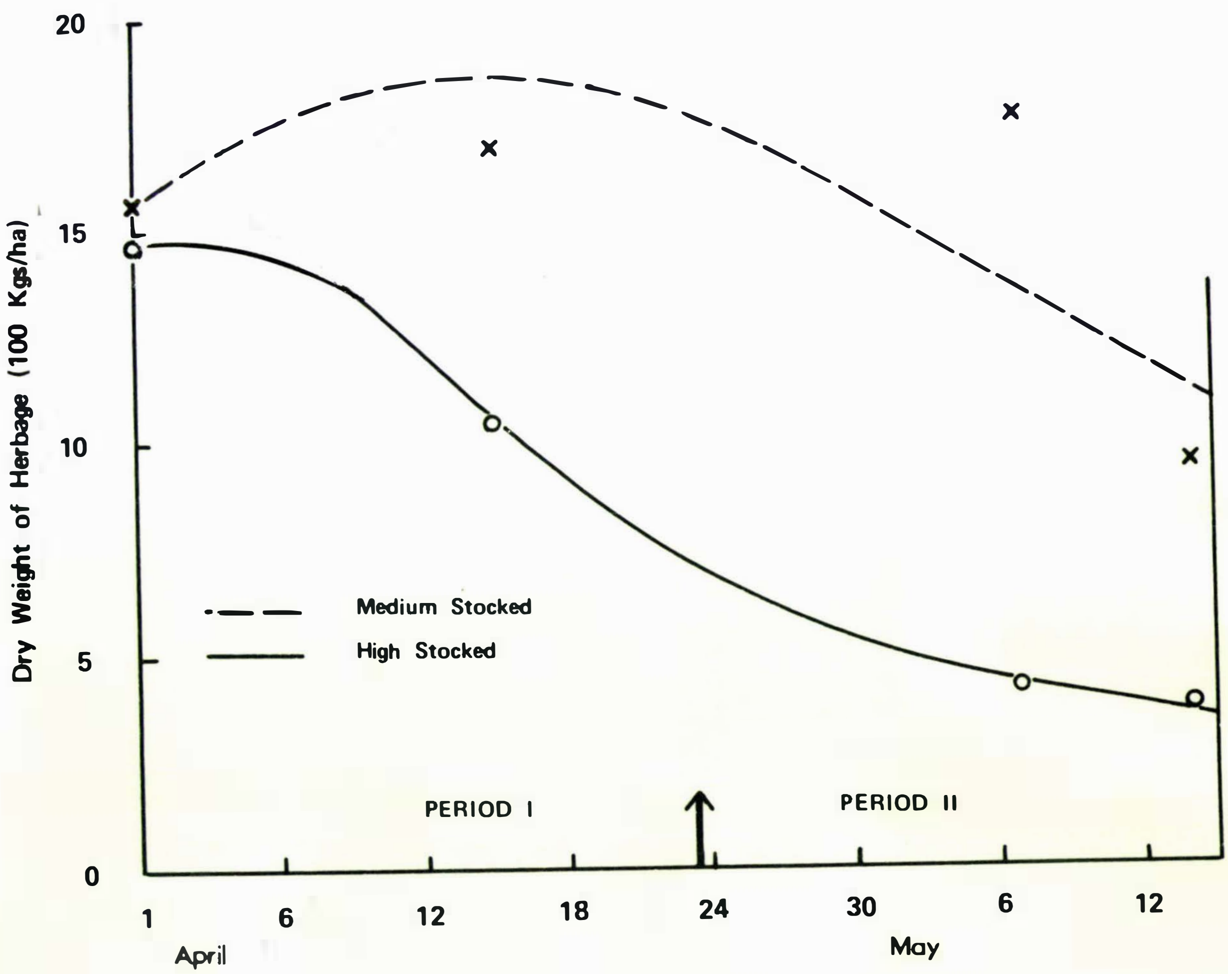

FIG. II. 1 CHANGES IN TOTAL DRY MATTER AVAILABLE

Plate 2.

General and close-up view of the pastures prior to commencement of Experiment I.

Plate 3.

Close-up view of the medium stocked (upper) and high stocked (lower) pastures at the end of Experiment I.

From similar levels at the commencement of the experiment the total dry matter under the medium treatment appears to have risen to nearly 2000 Kgs/ha and then declined to about 1000 Kgs/ha at the end of the trial, but under the high treatment the availability appears to have declined steadily to less than 500 Kgs/ha at the end of the trial. Using these curves an estimate of the mean availability under each treatment was made. During period I on the high treatment the availability was 1300 Kgs/ha and during period II 500 Kgs/ha. For the same periods on the medium treatment the mean availabilities were 1800 Kgs/ha and 1500 Kgs/ha respectively.

Plates 2 and 3 show the amounts of herbage present on the pastures at the commencement and end of the experiment.

(ii) Growth Rates.

The mean daily growth rates are shown in Table II.2. Because of the difficulty in choosing representative sites in a sward and a small number of samples per plot the coefficient of variation varies considerably between records, from 3.1 to 76.6. However the pattern is for the high growth rates at the commencement of the experiment and falling during the trial. At the end of period II there is negligible growth on the high treatments but still a low rate of growth on the medium treatment. The initial high rates of growth are probably due to the very favourable nitrogen conditions after the summer dry period and the addition of further nitrogen fertilizer. The rate of decline in growth rate under the high treatment is considerably greater than under the medium treatment particularly during period II.

Table II.2. Mean Daily Growth Rates (Kgs/ha/day).

	Stocking rate.			
	Medium	± S.E. of mean	High	± S.E. of mean
30 March to 15 April	63.9	9.87	87.5	2.74
15 April to 30 April	34.0	6.20	51.2	19.25
30 April to 14 May	29.0	22.20	0.0	4.76

(iii) Botanical Composition.

Throughout the experiment dead matter represented a high proportion of the total dry matter under both treatments (see Table II.3). Amongst the green component species other than cocksfoot were a minor part of the herbage available. The main contaminants present were perennial ryegrass, [illegible] *poa annus*, *poa trivialis* and Yorkshire fog (*Holcus lanatus* L).

Under the high treatment, the relative contribution of green cocksfoot fell, and the dead matter rose during the experiment. However this trend was reversed under the medium stocked treatment, with the % of green cocksfoot increasing and the % of dead material declining.

Table II.3. Botanical Composition (% dry matter).

	Medium Stocked			High Stocked		
Date	Cocksfoot	Other Spp.	Dead	Cocksfoot	Other Spp.	Dead
31 March	36.6	5.4	58.0	50.6	11.9	37.6
23 April	23.0	6.0	71.0	21.6	4.9	73.6
14 May	44.3	13.1	42.7	34.0	13.6	52.5

(iv) Pasture Height.

The changes in the height of the sward under the 2 treatments are shown in Fig. II.2. These height measurements are taken from the same tillers sampled for green leaf length. These measurements agreed closely with estimates made on three occasions of clump heights and are therefore used as representative of the pasture height.

Under the high treatment the sward was always shorter and the green leaf length less than under the medium treatment. The greatest rate of reduction in height and green leaf length occurred during Period I in both treatments. During period II although a further reduction occurred the swards remained relatively uniform throughout. The mean heights of the sward during period I were 62.0 mm and 26.1 mm for the medium and high treatments and 36.6 mm and 11.9 mm respectively during period II (See Table II.4).

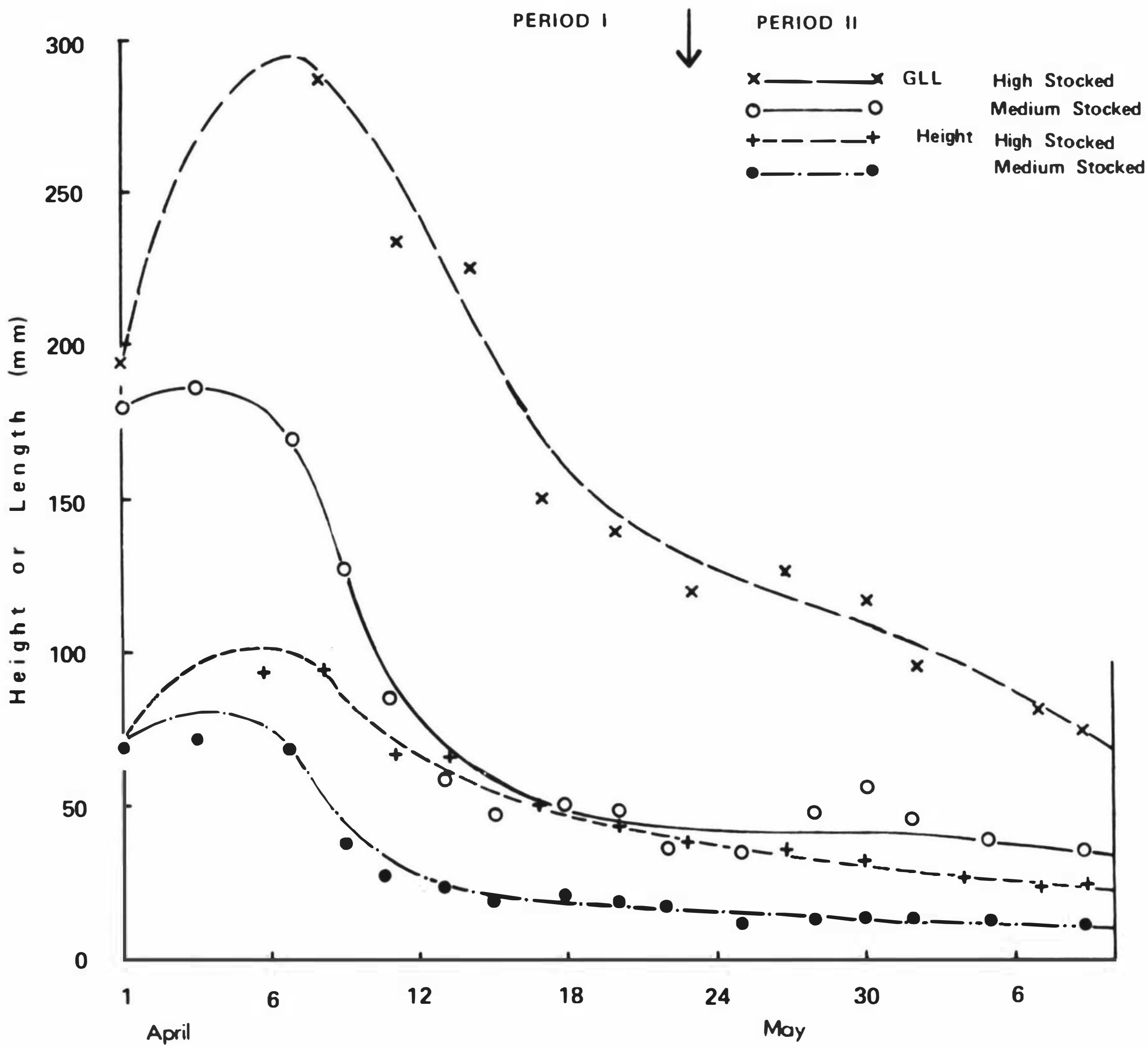

FIG. II. 2 CHANGES IN MEAN HEIGHT AND GREEN LEAF LENGTH (G.L.L.) OF SWARD

Table II.4. Mean Heights (mm) and Green Leaf Lengths (G.L.L.) (mm) of Tillers

	Medium Stocked				High Stocked			
	Height	± S.E.	G.L.L.	± S.E.	Height	± S.E.	G.L.L.	± S.E.
Period I	62.0	7.77	194	27.0	36.6	7.22	96	19.1
Period II	26.1	2.27	98	10.0	11.9	0.32	44	3.1
Period I & II	45.4	6.44	150	13.6	26.4	5.11	82	21.1

(v) Tiller Counts.

The tiller counts for each treatment are summarised in Table II.5. From similar densities at the commencement of the experiment tiller numbers increased over 100% under the medium treatment and nearly 50% under the high treatment. This increase was due to an increase in the number of cocksfoot tillers and also those of the contaminant grasses, particularly *poa* species. Although other species represent a large proportion of total tillers they were for the most part very small in size as is indicated by the much smaller contribution of "other species" to the total dry matter available (Table II.3). The numbers of dead tillers declined under the medium treatment but increased under the high treatment. The relatively low number of dead tillers contrasts with the high proportion of total dry matter that was dead material, suggesting that at least some of this dead material must have been coming from death of leaves on live leaves as well as from dead tillers *per se*.

The difference in the rate of increase in tiller numbers under each treatment is due mainly to the unequal increase in the number of new cocksfoot tillers. This was seen in the proportion of cocksfoot tillers that could be categorised as "young" at each observation (2 leaves or less). These fell from 34.9% to 16.4% under the high treatment and from 36.9% to 18.2% under the medium treatment over the period March 29 to May 12.

Table II.5. **Tiller Counts (number/m^2).**

Medium Stocked						
Date	Cocksfoot	± S.E.	Other spp.	± S.E.	Dead	± S.E.
29 March	5150	500	1440	724	540	214
25 April	7120	954	1860	607	480	51
12 May	11800	1290	3330	1637	82	8
Mean	8023	1472	2290	573	367	144
High Stocked						
29 March	5850	806	1660	923	132	97
25 April	6080	291	2540	867	428	71
12 May	7120	326	3880	648	326	31
Mean	6350	391	2690	645	296	87

Table II.6. **Mean Weekly loss of Tillers by Uprooting from 15 April to 12 May (number/m^2).**

Medium Stocked						High Stocked					
Cocksfoot	± SE	Other spp	± SE	Dead	± SE	Cocksfoot	± SE	Other spp	± SE	Dead	± SE
83	15.4	52	24.2	26	19.7	129	23.9	68	7.7	30	4.8

After about two weeks uprooted tillers were noticed on the plots and in largest quantities under the high treatments. Since the quantities appeared to be significant an attempt was made to estimate the magnitude of the losses. In each plot

6-0.3 metre-square quadrat positions were marked and at 2-4 day intervals were examined and the number of freshly uprooted tillers recorded. These tillers were categorised similarly to the tillers counts and the results are shown in Table II.6.

Under the high stocked treatment approximately 2% of the cocksfoot tillers were uprooted each week and under the medium treatment about half this. Towards the end of the experiment the number of tillers being uprooted was declining under the high treatment but increasing under the low treatment.

The percentage of other species uprooted was 2½% and 2½% and the percentage of dead tillers uprooted 10% and 7½% under the high and medium treatments respectively.

Animal Records.

(i) Liveweight.

The changes in mean liveweights are shown in Table II.7. From similar liveweights at the commencement of the experiment, the ewes under the medium treatment gained weight significantly (5%) while the ewes under the high treatment lost weight (significant at 10%). On the medium treatment the gain in weight was significant during both periods and on the high treatment the loss in weight was significant during period I.

Table II.7. Liveweight Changes of Ewes (Kgs).

	Medium Stocked		High Stocked	
Date	Mean	± S.E. of mean	Mean	± S.E. of mean
31 March	42.91	1.55	42.00	0.79
22 April	46.26	1.55	40.25	0.79
15 May	49.21	1.55	39.48	0.79

(ii) Grazing Times.

The mean daily grazing time for the sheep on the high treatment was 9.22 hours compared with 8.43 hours on the medium treatment, as shown in Table II.8. The differences in grazing time were less during period II than period I.

From period I to period II there was a slight increase in grazing time under the high treatment but under the medium treatment grazing time increased about 1 hour 40 minutes. The pattern of grazing under the high treatment during period I showed that during the first week there was a relatively low daily grazing period of 7.08 hours but in the next 2 weeks the rate rose to 10.00 hours - higher than in period II.

Table II.8. Grazing Times (hours/day)

	Medium Stocked				High Stocked			
	No. of animals	Hrs/day	± S.E.	Range	No. of animals	Hrs/day	± S.E.	Range
Period I	2	7.55	0.453	4½–10	3	9.14	0.680	3½–15¼
Period II	2	9.31	0.264	6–12¼	3	9.30	0.314	7¼–11¾
Period I & II		8.43	0.880			9.22	0.780	

Loss of Records.

The average number of originally marked tillers surviving at the end of period I was 174 in the high treatment and 193 in the low treatment. By the end of period II this number had fallen to 127 and 184 respectively. Of the 50 "youngest" tillers marked at the beginning of period II, 36 and 47 survived in the 2 treatments respectively. The loss of records was due to failure to locate marked tillers, displacement of marker, uprooting of tillers and decomposition of tillers. Such difficulties could arise for reasons such as complete defoliation, urine burn, buried under dung, trodden into ground etc. The largest number of losses occured under the high treatment during period II (See Table II.9). The losses during period II were significantly greater than those in period I for the high treatment but not for the medium treatment.

Colour of loop seemed to have little effect on the losses. 15 records were lost where tillers were marked with red loops, 12 were white, 11 where blue and 13 where orange. The differences were not significantly different. Of the tillers marked with yellow loops at the beginning of period II 7 were lost. The losses of records per transect varied considerably within treatments and plots. On high plots the losses ranged from 3 to 14 and on the low

Table II.9. Reasons for Loss of Tillers Records, and Losses in each Category.

	Medium Stocked		High Stocked	
Period	Period I	Period II	Period I	Period II
No. tagged (mean of 2 plots)	200	225	200	250
Total Lost	7	10	26	54
Uprooted	2	1	6	8
Displaced	2	N.R.	9	30
Death due to complete defoliation	0	1	1	0
Death from other causes	3	4	7	10

N.R. = not recorded

plots from 1 to 4. On plot 1 of the high treatment the losses on transect 10 were significantly greater than those on transects 3 and 4 but within other plots there were no significant differences between transects. The highest losses on the high plots were observed on transects where the cocksfoot plants showed a very pronounced crown. When the sward was very closely grazed tillers appeared to be readily lost by uprooting.

Defoliation of tillers.

(a) Frequency of Defoliation.

(i) All Tillers:

Sixteen observations (9 in period I, 7 in period II) were made for the high treatment and fourteen observations (7 in each period) were made in the medium treatment. By comparing the measurements made on successive dates, assessments were made of the defoliation of individual tillers between observations (Table II.10). Individual tiller records contributed to a clump mean (4 or 5 tillers) because tillers within a clump could not be considered independent because of their close physical proximity. Because of lost records, for reasons already described, some clump means were not available and so estimates were analysed as the mean frequency per transect rather than per clump as was planned.

On average tillers were grazed once every 5-7 days under the high treatment and every 7-8 days under the medium treatment. The frequency under the high treatment was significantly greater than under the low treatment. The frequency of defoliation decreased significantly from period I to period II for the high treatment but showed a slight non-significant increase for the medium stocked treatment. In both periods the frequency under the high treatment was significantly greater than under the medium treatment.

The differences between transects were tested using Duncans Multiple Range Test (Duncan, 1955). While differences existed between transects of different plots, there were less significant differences within plots. At the 5% level of significance transects 3 and 4 on plot 1 of the high treatment were significantly less than transect 2, and on plot 2 of medium treatment transect 5 was significantly greater than transects 1 and 10. These differences suggest that some areas of the plots were grazed less regularly than others.

Table II.10. Frequency of Defoliation (days between defoliations).

	Interval between each defoliation			
	Medium	± S.E. of mean	High	± S.E. of mean
Period I (24 days)	8.1	0.22	5.0	0.07
Period II (19 days)	7.7	0.20	6.9	0.22
Period I & II (43 days)	7.3	.07	5.4	0.02

L.S.D. period x treatment = 0.45 (5%)

For each observation date the grazed and ungrazed tillers were compared by the length of green leaf (G.L.L.) present before defoliation. Table II.11 shows the G.L.L. as well as the heights of the tillers. The G.L.L. of grazed tillers was generally greater than that of ungrazed tillers. The differences were significant (using an unpaired test) at the 5% level or better for 9 of the 11 observations on the medium treatment and in 7 of the 16 observations on the high treatment. The heights of the same tillers show that the grazed tillers were also always higher than the ungrazed tillers prior to defoliation. The significance of these differences was not

Table II.11. Mean Green Leaf Length and Height of Grazed and Ungrazed Tillers (cm) Before Grazing.

Date	Mean G.L.L.			Height	
	Grazed	Ungrazed	Sig.	Grazed	Ungrazed
Medium Stocked.					
8 April	32.55	24.83	***	10.52	7.20
11 "	27.98	18.54	**	7.93	5.32
14 "	22.65	17.88	0.1	6.38	5.93
17 "	17.52	12.85	**	5.96	4.62
20 "	14.91	12.74	*	4.92	3.95
23 "	13.36	10.50	***	4.33	3.41
27 "	13.78	11.79	*	3.69	3.15
30 "	13.27	9.85	***	3.56	2.45
2 May	10.57	8.07	**	2.98	2.24
7 "	8.55	7.85	N.S.	2.37	1.97
9 "	8.78	6.87	**	2.42	1.95
High Stocked.					
30 March	19.30	17.58	N.S.	6.33	6.65
3 April	21.28	14.81	**	8.09	5.77
7 "	18.42	14.58	*	7.12	5.50
9 "	13.01	10.96	N.S.	4.28	3.76
11 "	9.13	7.30	*	2.99	2.45
13 "	6.46	5.29	N.S.	2.35	2.01
15 "	5.03	4.56	N.S.	2.14	1.65
18 "	6.00	4.73	**	2.20	1.35
20 "	5.28	4.59	N.S.	2.04	1.77
22 "	4.27	3.17	***	1.73	1.36
25 "	3.67	3.39	N.S.	1.45	1.24
28 "	5.13	4.59	N.S.	1.35	1.17
30 "	5.57	5.63	N.S.	1.44	1.13
2 May	5.21	4.45	*	1.31	1.37
5 "	4.47	3.95	N.S.	1.14	1.00
9 "	4.50	3.42	**	1.07	1.06

* P = 0.05   ** P = 0.01   *** P = 0.001

tested.

The pattern of tiller selection was also examined by comparing the subsequent frequency of defoliation of tillers grazed or not grazed at the beginning of the recording period. Those grazed during the first 8 days under the medium treatment were compared with the ungrazed, and during the first 3 days under the high treatment. The results are shown in Table II.12. Under the medium treatment those not grazed initially were grazed significantly (0.1%) more frequently than those which had been grazed previously. By comparison in the high treatment those tillers not grazed initially were subsequently defoliated at a similar frequency to those previously grazed.

Table II.12. Subsequent Defoliations of Tillers Previously Grazed or Ungrazed (no. of defoliations)*

	Medium Stocked		High Stocked	
	Grazed before 8 April	Ungrazed before 8 April	Grazed before 3 April	Ungrazed before 3 April
No. of tillers	113	254	46	207
No. defoliations	5.22 ± 0.174	5.77 ± 0.105	7.76 ± 0.280	7.27 ± 0.157

* per 33 days for medium and 38 days for high

(b) Severity of Defoliation.

By comparing the mean G.L.L. of tillers before and after defoliation an estimate can be made of the severity of defoliation. To this figure a correction is applied for the growth occuring between observations based on the mean increase in G.L.L. of ungrazed tillers over the same time interval. The results are expressed as the mean G.L.L. removed per defoliation and to this value expressed as a percentage of the mean G.L.L. available per tiller before defoliation (See Table II.13 and Figure II. 3(A) and (B)). The mean number of tiller records contributing to each estimate in Fig. II.3 is 50 (range 21-70).

Over the experimental period there is a steady decline in the G.L.L. removed under both treatments, levelling out

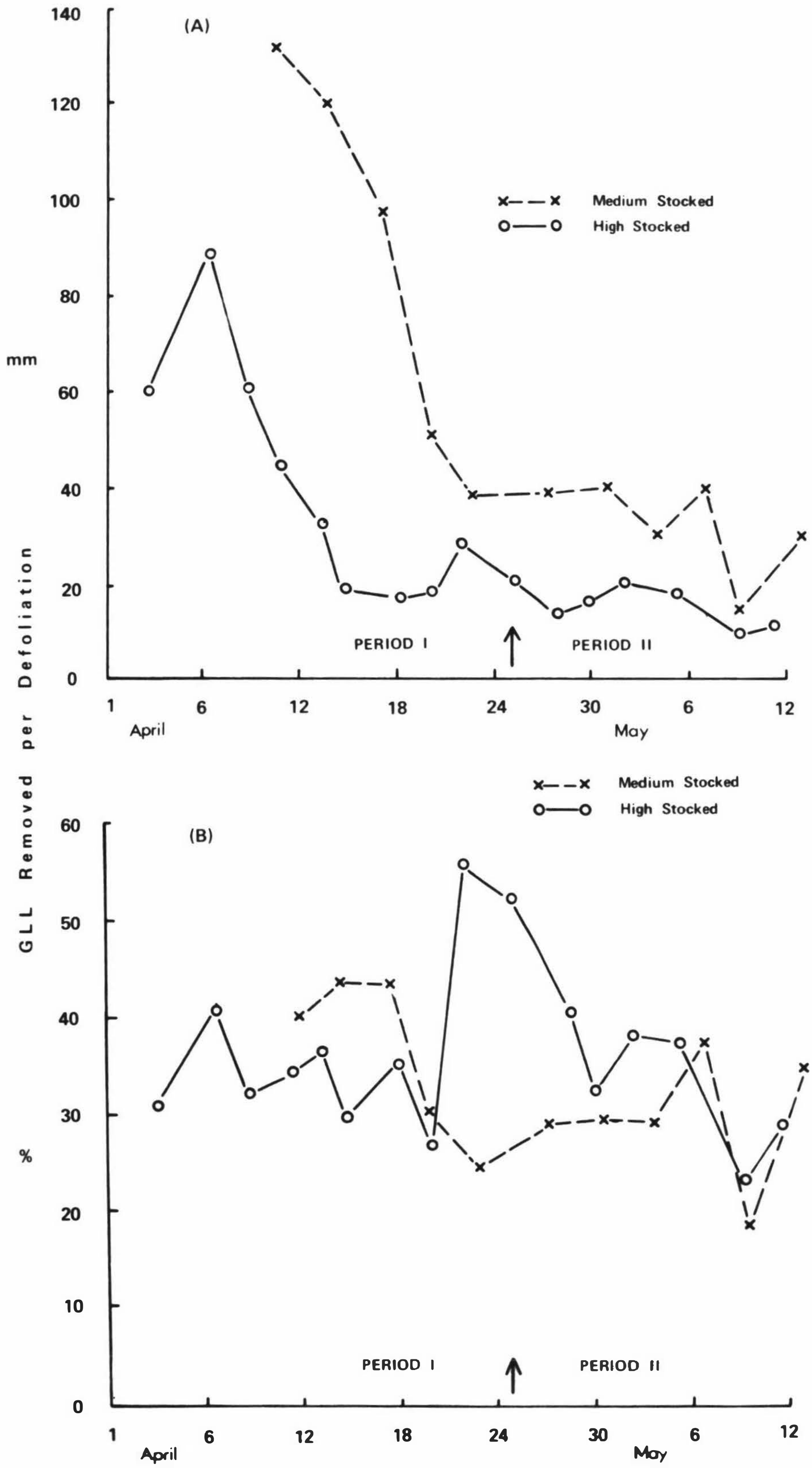

FIG. II. 3 SEVERITY OF DEFOLIATION OF INDIVIDUAL TILLERS
(A) Mean GLL removed (m.m) and (B) % of GLL removed, at a single defoliation.

during period II. The mean G.L.L. removed was significantly greater under the medium treatment than under the high period and during period I than during period II. The length removed from tillers in the medium treatment was significantly greater than the high treatment during period I but during period II although the difference was still quite marked this was not significant.

When the severity is expressed as a percentage green leaf length removed, 33.29% of G.L.L. was removed under the medium treatment and 36.71% under the high treatment. This difference was not significant. There was no significant difference in the % removed in either period or within a treatment in either period. However the % removed remained constant under the high treatment but declined under the medium treatment.

Table II.13. Severity of Defoliation of Individual Tillers as Length of G.L.L. (mm) and as Percentage of G.L.L. removed (%).

		mm	± S.E.	%	± S.E.
Period I	Medium	88.44	9.37	36.51	3.36
	High	41.93	9.37	36.51	3.36
Period II	Medium	33.33	9.37	30.51	3.36
	High	17.28	9.37	36.97	3.36
Period I and II	Medium	58.38	6.50	33.29	2.33
	High	31.14	6.50	36.71	2.33

(c) Age Categories of Tillers.

"Young" and "old" tillers were compared for frequency and severity of defoliation during Period I and during period II a further category of "youngest" tillers was also included. For estimates of the frequency, records from only one replication (plot 2 in both treatments) were used. The results are shown in Table II.14 (a) and (b).

During period I there was no significant difference between the number of defoliations for either category of tiller.

However during period II the "youngest" tillers were grazed less frequently than "young" and "old" tillers on the medium treatment, whereas on the high treatments all tillers appeared to be grazed equally.

The severity of defoliation was calculated from all estimates of individual tillers within a category in each period rather than the mean of the categories for each observation interval. This was done because of the small number of available records in the "young" and "youngest" categories at some observation dates. Under the medium treatment "old" and "young" tillers appear to be grazed with similar severity in each period. While the "youngest" tillers may be grazed more severely during period II this may be due to the small size of the sample. Under the high treatment the most noticeable feature is the lower severity of the "youngest" tillers during period II especially in relation to "young" tillers.

Table II.14(a) Frequency of Defoliation of "Old", "Young" and "Youngest" tillers (days between defoliations).

	Period I				Period II					
	Old	± S.E.	Young	± S.E.	Old	± S.E.	Young	± S.E.	Youngest	± S.E.
Medium	7.9	0.34	7.6	0.38	6.7	0.28	6.9	0.43	10.5	1.23
High	4.8	0.18	4.8	0.14	6.3	0.21	6.1	0.57	6.3	0.47

L.S.D. (period II) category x treatment = 2.67 (5%)

Table II.14(b) Severity of Defoliation of "Old", "Young" and "Youngest" tillers (% G.L.L. removed per defoliation)

	Period I		Period II		
	Old	Young	Old	Young	Youngest
Medium	28.70	30.79	28.32	29.85	35.09
High	36.77	30.75	34.78	41.11	26.58

(d) Defoliation of Individual Leaves.

The pattern of leaf selection within tillers was examined by comparing the number of tillers with leaves available in three positions; 1 - youngest leaf, 2 - next youngest leaf and 3 - an older leaf, with the number of tillers with the same leaves grazed. The estimate of the available tillers is made from the transects on which the G.L.L. was measured. The results are shown in Fig. II.4.

The leaves in positions 1 and 2 were selected more frequently than those in position 3. During period I nearly all tillers had three leaves available for defoliation but during period II there were fewer tillers with a third leaf particularly under the high treatment. The selection of leaves in each category was very similar over the experimental period for each treatment. However because of the marked decline in leaf number under the high treatment there was a greater proportion of the available third leaves selected.

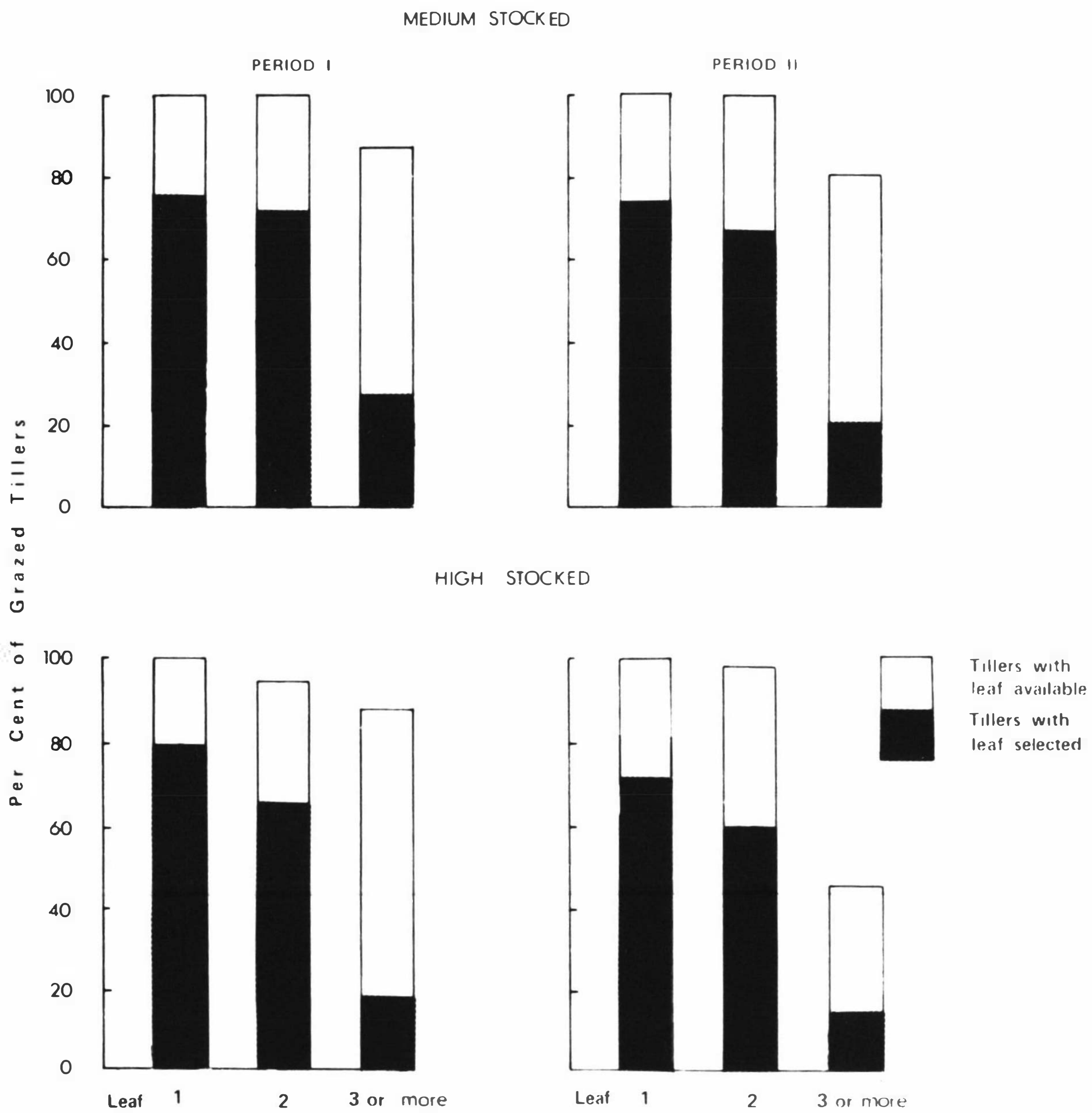

FIG. II. 4 PATTERN OF LEAF SELECTION ON TILLERS
Showing % of tillers with youngest (1), intermediate (2) and oldest (3 or more) leaves available (unshaded) and selected (shaded)

E. Discussion.

(i) Of Techniques.

As a preliminary to discussing the experimental results it is necessary to examine the validity of the techniques and also any limitations these may place on the results obtained.

Pasture Measurements.

In this study pasture measurements have been used to define the changing conditions of the plant environment which the animal is defoliating as a result of both the changing climatic conditions and the action of the sheep itself e.g. treading, defoliation and the return of dung and urine. The measurement of total dry matter available was affected by the difficulty of cutting material equally to ground level on an uneven surface and this probably led to seemingly high estimates of availability on some dates. As plots decreased to very low availabilities (e.g. under high stocking rate) it is possible that more soil tended to be picked up in the sample, using a shearing handpiece. This could have the effect of slightly overestimating the availability and possibly altering the botanical composition. The unusually high dead matter content on May 12th may have resulted in this way, as the dry matter assessment had, of necessity, to be taken very close to the soil surface.

The estimate of growth rate represents the balance between new growth and losses associated with death and decomposition. Besides the difficulties mentioned above, the selection of the caged sampling site as being representative of the whole pasture may have added a further limitation to accuracy. The high standard errors of the estimates probably reflect those difficulties. It may be possible to "pair" a single open cut with a caged cut to determine more accurately the growth rate (Lynch 1966, p.74). This method was used for Experiment II.

The method of determining the mean height of the pasture has been discussed (p. 26). This very simple technique seems well suited to evenly grazed dense pastures. Its accuracy may be reduced when pastures are taller and variability is greater; as may have occurred at the beginning of the experiment with the characteristic "patchy" effect (See Plates 1 and 2).

Tiller Identification.

The technique of tiller identification was essentially similar to that described by Hodgson (1966, 1969). A significant difference however between this experiment and those reported by Hodgson was the smaller number of lost records in this experiment. There are a number of possible reasons for this. By placing marked tillers together in clumps only rarely was a marked tiller not found at a subsequent observation. Hodgson (1969) observed quite high losses due to uprooting, complete defoliation, and death due to complete defoliation. The difference in this experiment may have been due to the structure of the cocksfoot tillers compared with those of ryegrass. Because leaves are anchored at or near ground level there may be less stem for the animal to grasp and uprooting of the whole tillers may be less likely. Other factors associated with soil structure and root development could also be important. In this trial completely defoliated tillers were not categorised as lost records. It was considered that they were still very much part of the defoliation pattern and that to exclude them may be giving an incorrect picture of the true defoliation pattern of the whole pasture. In this experiment very few deaths occured as a result of complete defoliation. This is possibly accounted for by the position of the growing point of cocksfoot at this time of the year, which appears to be approximately 10 mm below the soil surface (see Experiment II).

The loss of records was greater during period II than during Period I. This was probably due to the shorter sward conditions enabling markers to be more easily lifted and displaced. Also during period II tillers were uprooted more easily. This effect was particularly noticeable on areas of the paddock where the cocksfoot had developed a high crown and tillers appeared to break off more easily.

The colour of marker rings and their effect on grazing sheep has previously been discussed (Hodgson 1966, 1969; Hart, 1970). This study showed very little variation in losses due to colour of markers; however none of the colours used was similar to that of the sward.

Frequency of Defoliation.

The frequency of defoliation may be slightly underestimated due to the short period of observation in each period of the trial; also due to edge effects and because of the possibility of individual tillers being defoliated more than once between observations. Although this latter situation is possible it is unlikely to have occured very often because the mean observation interval was quite short viz. 3 days for both treatments.

No measure was made of the effect of handling on the growth of the marked tillers which has been shown to be of possible significance in cocksfoot (Grasslands Res. Inst., 1967). If such effects occured the pattern of frequency and intensity may vary slightly.

Severity of Defoliation.

The estimation of G.L.L. based on the measurement of all leaves to ground level may not give a true indication of the pattern of change in green leaf alone on tillers. The length of some leaves would have included a sheath component and some of the youngest leaves would have been partially enclosed by older leaves. These regions may be less active photosynthetically than that of the lamina, as has been shown to occur in other members of the Graminae (Thorne, 1959). This means that estimates in this study may underestimate the severity of defoliation of the individual tiller. Also estimates when compared with those made by Hodgson, based on green lamina alone, may be a little lower. It must also be remembered that though dead or brown leaf was not included in the G.L.L. there were different ages of leaves present representing a range of photosynthetic efficiencies; efficiency declining from young to old leaves.

(ii) Of Results.

Pasture Measurements.

The pattern of declining availability during the course of the experiment is the result of the effect of removal by defoliation, the declining growth rate and losses by decomposition. Because conditions were quite dry during the course of the experiment it is likely that decomposition losses remained relatively small throughout the experiment, as suggested by the work of Floate (1970). He found that the rate of decomposition of pasture was greatly reduced as the moisture content of the soil declined. The rate of decline in availability of the high stocking rate treatment was greater than that on the medium treatment, which would be expected from the difference in animal numbers. It is unlikely however that the amount of material removed from this treatment was twice as great as that removed from the medium stocking rate treatment throughout the experiment, i.e. reflecting the difference in animal pressures. The reasons for this assumption will be discussed. Also the fall in growth rate was greater on the high stocking rate treatment than on the medium treatment.

The declining growth rate follows an expected autumn pattern due to decreasing solar radiation and temperature. However additional factors, due to the presence of the animals probably influenced this decline. Because of the prevailing dry conditions, and close grazing which developed especially on the high stocked treatment during period II, drying of the surface layers of the soil may have slowed growth through a nitrogen shortage (Mitchell, 1957). Cocksfoot is also susceptible to treading (Edmond, 1966) and close defoliation (Brougham, 1960) and this may have further reduced growth, particularly on the high treatment.

The pattern of change in height was related to the change in availability with a decline over the course of the experiment, after a temporary rise. After this rise the height fell at a faster rate than the availability which would be due to the low density of dry matter near the top of the sward. The rate of decline in height was considerably reduced during period II as the more dense region of the sward close to ground level was reached. This increase in density at lower levels was enhanced in this study by the high rate of tillering due to favourable light, temperature and nitrogen conditions, particularly initially.

It is difficult to determine whether grazing had any effect on the pattern of tillering. Investigations under controlled conditions show defoliation invariably reduces the rate of tillering although this may be for only a short time. However under field conditions the results are more variable (Langer, 1963). Cutting or grazing may increase tillering by improved light conditions at the base of the sward, (Mitchell and Coles, 1955).

While tiller density increased during the course of the experiment this was at a declining rate, the decline being more marked on the high treatment than on the medium treatment. This decline in rate was probably due to the declining conditions for growth of the plants with poorer light and temperature conditions as winter approached. The differential rate of decline on the two treatments may have been due to the greater treading effect exerted at the higher rate (Edmond, 1966).

The change in botanical composition indicated a greater proportion of dead material on the high treatment. This probably does not represent a greater amount of dead material between the 2 treatments although under the high treatment a greater number of tillers may have been destroyed by the animals uprooting and treading but more reflects the closeness of grazing of the two pastures. As availability declines and pastures become shorter the dead material present mainly at the base of the sward contributes a greater proportion to the available dry matter. It is likely that dead matter was more important in the diet of the sheep on the high treatment than on the medium treatment because of this closeness of grazing.

Animal records.

The changes in liveweight under the two treatments indicate the effects of the pasture conditions on animal performance since it is unlikely that other factors affected the animals, e.g. disease. The pasture may vary in quality or in such a way as to affect the animals' intake. Under the present conditions it is not likely that quality differed greatly between the two treatments as both represented autumn regrowth, however sheep on the high treatment may have consumed a greater quantity of dead material than their medium stocked counterparts. The major factor involved in the performance differences was probably differences in intake.

A number of investigators have examined the effect of availability on intake and performance of grazing sheep and have found an asymptotic relationship, with maximum intake and performance being realised in the range of 1500 kgs D.M. /hectare (either green or total) up to about 2000 kgs/hectare (Willoughby, 1959; Allden, 1962; Arnold, 1963). These studies were under Australian pasture conditions using merino sheep.

Table II.15 shows the relationships between herbage available and animal performance in this trial. The pattern of animal performance observed shows agreement with the cases cited, as the pastures on the medium treatment had a mean availability greater than 1500 kgs per hectare in each case while those on the high treatment were slightly below during period I but considerably so during period II.

However, merely to establish a relationship between intake and performance and availability may oversimplify the explanation. Some investigations have found little or no relationship between intake or rate of intake and pasture availability but have found pasture spatial arrangements,

Table II.15. Variation in Some Animal and Pasture Parameters and their Interrelationship.

	Medium		High	
	Period I	Period II	Period I	Period II
L.Wgt Changes (Kgs)	+3.4	+2.9	-1.7	-0.8
Pasture Hgt (cm)	6.2	2.6	3.7	1.2
Total D.M. Avail. (100 Kgs/ha)	18.0	15.0	13.0	5.0
Green D.M. Avail. (100 Kgs/ha)	8.2	7.5	5.9	2.3
Stocking Rate (sheep/ha)	41.6	30.7	81.2	76.[illegible]
Total D.M./Sheep (Kgs)	43.7	50.0	16.2	6.5
Green D.M./Sheep (Kgs)	19.6	24.4	7.3	3.0

height and density, to be very closely related to the rate of intake (Wheeler, Reardon and Lambourne, 1963; Allden and Whittaker, 1970). The latter workers found that as the height of the pasture (Wimmera ryegrass *L. rigidum* Gaud) decreased from 7.7 cm to 3.7 cm the rate of intake declined seven-fold from 7.1 g. dry matter/min. to 1.0 gms D.M./min. The animals were able to compensate to some extent for this reduced intake by increasing grazing time. In this trial the differences in height of pasture between the treatments during period I was of a similar order of magnitude (6.2 cm to 3.7 cm) and intake probably declined as a consequence. However during period II the intake on both treatments should have been further reduced, which does not appear to have occured under the medium treatment. The increase in density of the pastures over period II, in particular on the medium treatment, is the probable explanation for this difference. In Allden and Whittaker's investigation the pasture density was considerably less than those observed in this trial (availability at 7.1 cm was less than 500 Kgs/ha (treatment C, experiment B) compared with over 1500 Kgs/ha at about 3 cm in this study (medium, period II), which may well have allowed the animals to maintain intake on the medium treatment during period II in this trial.

Recently Scoffield (1970) has suggested, for pasture similar to those used in this trial, that intake becomes limited once the available green matter falls below 100 lbs /animal. In this investigation the total available dry matter per animal exceeded 100 lbs/animal in the medium treatment during both periods but never approached this level at any stage in the high treatment. The observed changes in liveweight in the two treatments suggest agreement to his suggestion. The short-term nature of the present experiment may have had some effect on animal intake through compensatory intake and growth. However the differential effect of an enhanced intake on the medium treatment and a reduced intake on the high treatment, particularly during period I, would be unexpected if the animals were compensating for a previous poor plane of nutrition. Because the ewes used were dry appetite drive would not be expected to be as great as that from pregnant, lactating or younger animals and under adverse pasture conditions affecting prehension. Under such conditions intake would probably decline more readily. This reduced appetite drive may also explain the very small differences observed in grazing times between the two treatments and the relatively low ceiling (about 9½ hours) reached even under the extreme conditions.

Pattern of Defoliation.

(a) Frequency of Defoliation.

The estimates of the frequency of defoliation in this short-term experiment were similar to those observed for high stocked treatments on continuously grazed ryegrass swards in England (Hodgson 1966, 1969). The pastures in those studies were similar in density, height and availability to the cocksfoot pastures in the present study. Those studies, together with the results presented there, found defoliation to be very frequent, every 5 to 8 days, at high stocking rates (75 - 95 sheep/hectare) but at lower stocking rates (25 - 40 sheep/hectare) the frequency was only slightly less at 7 - 14 day intervals.

In this experiment, while the differences in frequency between stocking rates is significant in both periods the very noticeable feature is the sharp reduction in the size of this difference during period II compared with period I. This was due primarily to a reduction in the frequency under the high treatment but also a small rise under the medium treatment. In fact had the stocking on the medium treatment not been reduced during period II the frequency may have been even higher. The change in frequency on the medium treatment follows the pattern which has been found to occur in other situations where availability is reduced. Morris (1969) found that for lambs grazing cocksfoot pastures at the same stocking rate the frequency of defoliation varied inversely with the leaf area index (L.A.I.) of the pasture. As L.A.I. declined the frequency increased. Greenwood and Arnold (1968) also observed the greatest frequencies of defoliation when availabilities were least, in this case with merino sheep grazing an emerging annual grass sward. The mechanism of this frequency change is probably through a reduced size of bite occurring as pastures become shorter (Allden and Whittaker, 1970) necessitating a change in grazing behaviour as the animal endeavours to maintain intake. The number of bites per day increases as the rate of biting and grazing time is increased (Arnold, 1963 and others). This would lead to a more frequent defoliation of the individual tillers of a pasture.

The reduction in frequency under the high treatment may also be due to adaptations in the grazing behaviour of the sheep associated with pasture conditions. The efficiency of these adaptations to changing pasture conditions i.e. increased rate of biting and grazing time in relation to their ability to satisfy intake have not been determined. However what is more definite is that both of these adaptations are limited in the degree of change possible. The present suggested reasons for the limits observed is fatigue (McClymont, 1967; Arnold and Dudzinski, 1969). Once the maximum limit is reached this may either be maintained e.g. in grazing time, or as for the rate of biting, only be able to be maintained for a short time and will decline again for most of the day.

As suggested, adaptations will start to occur when the size of the bite declines. In this experiment no direct measure of size of bite was made but one of the calculated variables, the G.L.L. removed per defoliation (mm) is probably related to the size of bite. In pastures of even density this parameter would be well related to size of bite. The changes in the G.L.L. removed (mm) per tiller are shown in Fig. II. 3(A) and these show a sharp decline soon after the commencement of the experiment under the high treatment. Despite the increase in pasture density through the experiment a small size of bite was probably maintained during period II on the high treatment. On the basis of these changes in size of bite grazing behavioural changes probably occured. The grazing time records show that on the high treatment after the first week, the grazing time rose from 7.1 hrs/day to 10.5 hrs/day (Appendix II Table 6). After this period time of grazing was constant for the remainder of the experiment. Reasons for this low limit have been discussed. The rate of biting probably also rose but this may only have been maintained for short periods of the daily grazing time due to fatigue.

Under the pasture conditions experienced in the high treatment of this experiment considerable adaptations in grazing behaviour probably occured from early in period I giving rise to the high mean frequency observed over this period. During period II grazing conditions became increasingly difficult due to the shortness of the sward and the maximum time of grazing and rate of grazing reached. This could result in a lowered frequency of defoliation of the individual tillers in the sward as was observed in this study.

The very close pasture conditions may also have affected the grazing behaviour of the sheep through other factors. Allden and Whittaker (1970) noted that merino sheep grazing very short plots (less than 5 cm in height) did not appear to graze normally; they were restless, grazed intermittently and appeared to be very selective. These workers suggested that some factors other than the ability to prehend the herbage may influence the sheep's grazing behaviour under such conditions. No close observations of the animals' behaviour were made in this study but the sheep on the high treatment were noticeably more excitable at the presence of the observer when compared with animals on the medium treatment.

(b) Severity of Defoliation.

The change in length of G.L. removed from a tiller at a defoliation appears to be closely related to the mean height of the pasture or G.L.L. of the tiller (compare Fig. II 3(A) with Fig. II 2). It appears also that this relationship would explain the differences recorded between the stocking rates in G.L.L. removed. This finding differs from that of Hodgson (1969) who found the length of G.L.L. removed to increase with increasing stocking rate and shorter pastures. However in his study secondary tillers that developed on a tagged tiller during the course of the experiment were included in the estimated G.L.L. of such tillers and this added G.L.L. could have caused the measured G.L.L. removed to increase on his high stocked treatments.

The severity of defoliation, when expressed as % G.L.L. removed is more variable and does not appear to vary with stocking rate or pasture conditions. The magnitude of the values obtained for the percentage removed falls within the range of 20 - 40%, determined in previous studies (Morris, 1969; Hodgson, 1966) but falls below some very high estimates of 67% observed for heavy grazing pressures (Hodgson, 1969). Hodgson suggests that severity would increase with stocking rate and grazing pressure as the pastures become shorter.

The different growth form of cocksfoot where the leaves are anchored at or near ground level as distinct from their more elevated position on ryegrass tillers (particularly in the summer) for which Hodgson's experiment was conducted could give rise to lesser severity in this study, even though grazing pressures were higher than those observed by Hodgson. Because the decline in the G.L.L. removed per defoliation (mm) was so closely related to the declining height and G.L.L. of the pasture the severity of defoliation (% removed) does not alter greatly with pasture conditions or stocking rate.

(c) Age Categories of Tillers.

The pattern of defoliation of different aged tillers was very similar for both treatments and over the range of pasture conditions with the exception of the medium treatment during period II. The very close similarities during period I appear to be due to the similarities of structure of "old" and "young" tillers. Table II.16 shows the mean G.L.L. of the tillers in each category for each period. "Young" and "Old" tillers had very similar G.L.L's and showed no apparent difference in appearance or accessibility.

Table II. 16. Mean G.L.L. of "Old", "Young" and "Youngest" Tillers. (mm)

	Period I		Period II		
	Old	Young	Old	Young	Youngest
Medium	184.69	208.31	95.67	105.89	74.11
High	97.82	111.35	39.87	44.75	43.07

The small differences in the size of these tillers during period I are probably due to the very favourable climatic and edaphic conditions at the commencement of the experiment, allowing rapid establishment of new tillers. In this pasture, mature or old tillers had from 3 - 5 leaves per tiller. However during period II growing conditions were not as favourable and new tillers would possibly have been more affected by such conditions than old, established tillers. Garwood (1969) has emphasized that dry soil conditions can greatly affect the development of new tillers through their inability to "root" and draw nutrients. The small size of the "youngest" tillers was probably due to such conditions.

Canopy structure of the two pastures during period II might also have affected the accessibility of the different aged tillers to the animals. Under the medium treatment the canopy was quite dense compared with the more open canopy of the high treatment (Plate 3). Thus smaller tillers would have been more inaccessible under the medium treatment than under the high treatment, where all tillers were probably equally accessible. However the differences in the severity of defoliation of "young" and "youngest" tillers on the high treatment during period II may indicate some difference in the structure of these tillers that affects the ease of grazing, e.g. a more prostrate habit.

(d) Selection.

(1) Within Pasture.

Those tillers grazed within the pasture at any particular observation always had a greater G.L.L. and height than ungrazed tillers. This pattern agrees with the findings of Hodgson (1969).

Sheep graze in a horizontal direction across the face of the pasture (Arnold 1960, 1966) and because of this it would be expected that those tillers most prominent in the pasture would be grazed. In this study the height of tillers bears a close relationship to their G.L.L. and so these selected tillers would also have been the highest in the sward which would cause them to be grazed before shorter, smaller tillers. Although Hodgson used a ryegrass sward a similar explanation may apply to his results.

Even though the pastures in this study were relatively even after the initial stages there was some variation in the frequency with which different regions were grazed. These preferences may be related to height but other factors are also possible. In plot 1 of the high stocked treatment transect 3 which showed a very low grazing frequency had the shortest mean height of all transects on this plot. In plot 1 of the low stocked treatment the transect of lowest grazing frequency also corresponds with lowest mean height while the transect of greatest frequency has the greatest height. However on plot 2 of the low treatment, transect 5 had the greatest mean height but a low frequency. It appears that the sheep grazed the tallest areas more frequently as a general rule but that there were exceptions. A greater dead matter content present on the transect 5 may have accounted for this reduced frequency or some unknown local palatability factor.

While some areas of the paddock were grazed more frequently than others there was no visible indication of the development of a patch grazing effect over the pasture in either the medium or high stocked treatments. The failure of tillers initially defoliated to be grazed any more frequently than tillers not initially selected probably reflects this observation. The significantly greater frequency of grazing of tillers initially ungrazed in the medium treatment does not mean that the initially grazed tillers were subsequently selected against. When the two categories were compared with the initial period included, their frequencies are quite similar.

(2) Within Tillers.

The youngest leaves on tillers were most frequently selected under all of the conditions of pasture examined. Morris (1969) suggested that the relative inaccessibility of the older leaves affected their selection and it is likely that such was the case here particularly during period I when the pasture was taller. During period II the younger leaves were probably still not accessible because they are the expanding leaves of the tiller in contrast to the older leaves where expansion has ceased. However the very open canopy occuring under the high treatment in period II would have allowed these older leaves to be more accessible giving rise to the higher proportion of available leaves in this position being selected.

CHAPTER III. EXPERIMENT II.

A. Introduction.

While the pattern of defoliation has been examined in a number of different pasture conditions, using different stocking rates and breeds of sheep (Hodgson 1966, 1969; Arnold and Greenwood, 1968; Morris, 1969), it is still not clear whether the pattern of defoliation differs between two breeds of sheep under the same conditions of pasture and management. This experiment examines the pattern of defoliation of mature merino and romney wethers grazing a 4 year old cocksfoot sward.

The merino breed was chosen because observations of the condition of pastures after a winter/spring grazing by merino and romney ewes on the Tuapaka agronomy area in 1968, indicated that differences may exist between breeds. At similar stocking rates, at the end of the spring season, the "romney" pastures were evenly and closely grazed while the "merino" pastures showed an extremely patchy nature; small areas of tightly grazed pasture were scattered through large areas of tall, mature herbage. It was thought that the merino sheep may be more selective, confining their attention more to areas first grazed than the romney breed.

B. Materials.

Location and Layout.

The experiment was carried out on the same research area of the Tuapaka research farm as Experiment I. A cocksfoot plot was fenced to give two plots of 0.065 hectares. In this trial due to insufficient suitable plots being available, replication was not possible. However the variation within the paddock selected and divided was not considered excessive, and the measurement intensity on each treatment was kept at a high level.

Experimental Animals.

Three, 2-year old merino wethers and three, 2-year old romney wethers of similar mean liveweights were allocated to each plot on June 30th. The mean stocking rate throughout the experiment was 46.2 sheep/hectare in each treatment.

C. Methods.

Pasture Management.

Prior to the experiment the plot had been used in the trial described in Experiment I, receiving the same fertilizer treatments. No additional fertilizer was applied to the plots before the commencement of the experiment. At the start of the trial, the plots carried about 2,000 Kgs. D.M/hectare and were about 150 mms high.

As in Experiment I, the trial was divided into two periods; the first of 3 weeks from July 1st until July 25th. At the end of period I in an attempt to examine the pattern at a lower level of availability no measurements were recorded on the romney area for one week and the merino area for two weeks. Thus the second period for the romney trial was from August 1st until August 21st and the merino trial from August 6th until August 26th.

Tiller Identification.

Tillers were ringed in the same manner as in Experiment I except that 24 tillers were marked per transect (in 6 clumps) to give a total of 240 tillers marked per treatment. Because of slow tiller initiation occuring during the winter no category of "youngest" tillers was marked at the commencement of period II.

Pasture Measurements.

Pasture availability, botanical composition and tiller density was recorded as in the stocking rate experiment. The measurement of growth rate was slightly modified from the previous experiment. The cages were placed and an open cut made from an adjacent area comparable with the caged site.

Together with the measurement of tiller density, on two occasions during the experiment 10 tiller cores were dissected to determine the depth of the apex of the tiller. This was done by clipping the tillers flush with the ground level, dissecting them out of the core and measuring the vertical depth of the root : shoot junction below ground level. On each core a number of the tillers dissected out were split open and the height of the growing apex above the root : shoot junction was measured under a binocular microscope. The difference between this height and the depth of the root : shoot junction gave the depth of the shoot apex.

Animal Measurements.

On three occasions during the experiment, liveweight of the sheep was recorded using a "Salter" spring balance and tripod.

Tillers Records.

At each observation date (see Appendix III Table 1.) tillers were examined and recorded in the same manner as in Experiment I.

Statistical Analysis.

Since only a single replication for each treatment was used the frequency of defoliation was determined by analysis of variance considering the 60 clumps within each treatment as independent samples.

D. Results.

Pasture Measurements.

(i) Availability:

An estimate of the changing quantities of total dry herbage for each treatment is presented in Fig. III.1. Initially the rate of decline was slightly greater on the "romney" treatment than on the "merino" treatment. However this soon changed to a similar rate of decline in availability on both treatments, the difference being maintained at approximately 300 Kgs/hectare.

The mean pasture availability during period I was 1690 Kg/ha on the romney plot and 2040 on the merino plot. During period II because the merino treatment started a week later than the romney treatment the mean availabilities were closer; the merino treatment at 1140 Kg/ha versus 1010 Kg/ha for the romney treatment.

(ii) Growth Rate:

Estimate of the mean daily growth rates are shown in Table III.1. The trend indicated by the estimates is an increase in the rate of growth from June 29 to August 24 on the merino grazed pastures while on the romney grazed pastures daily growth rate rose sharply in late July then declined almost as sharply in August.

Table III.1. Mean Daily Growth Rates (Kgs/ha/day).

	Romney	± S.E. of mean	Merino	± S.E. of mean
29 June to 17 July	- 11.9	4.10	- 17.8	4.80
17 July to 3 August	+ 29.1	3.00	+ 11.4	1.25
3 August to 24 August	+ 5.05	2.95	+ 17.7	3.40

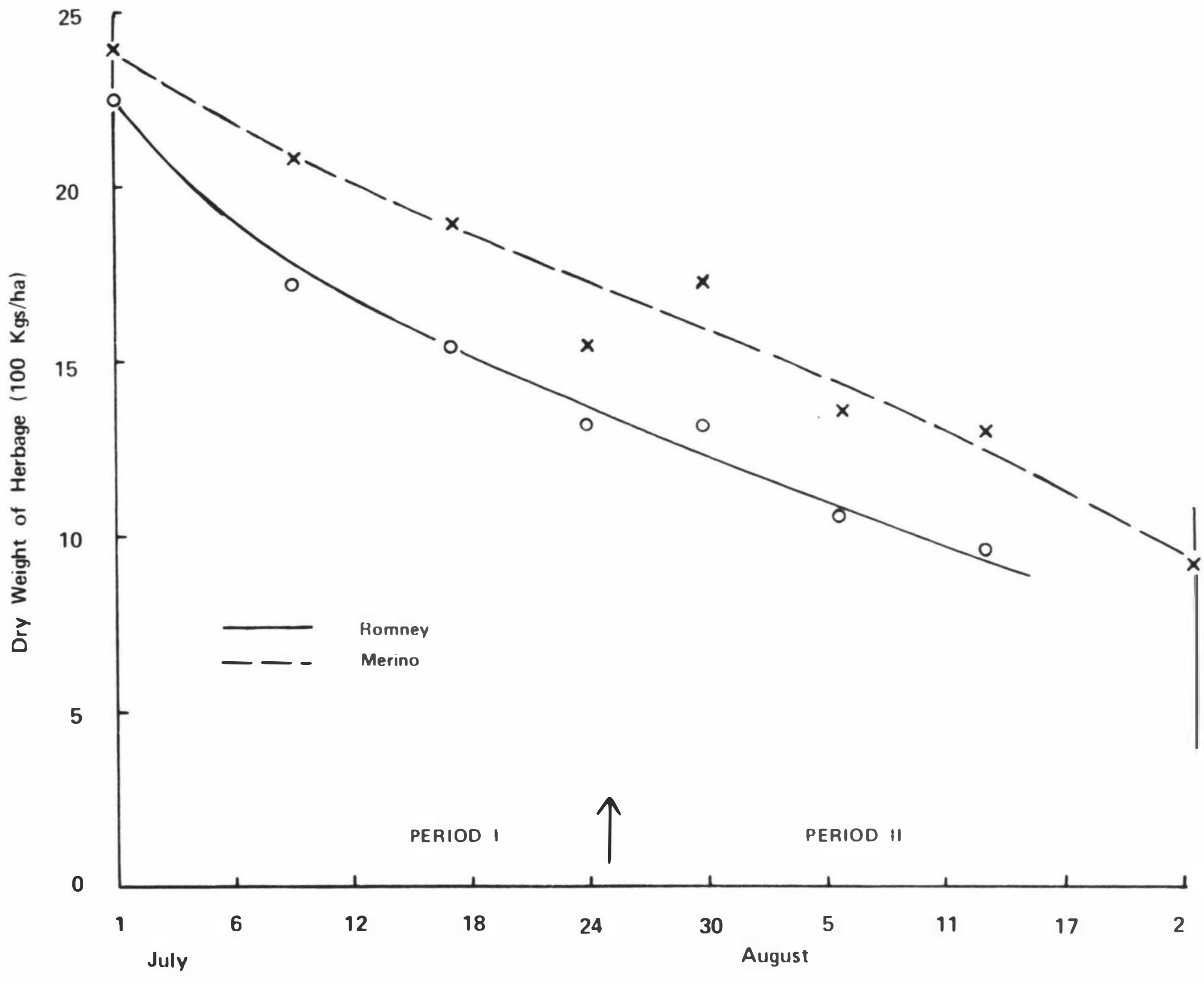

FIG. III. 1 CHANGES IN TOTAL DRY MATTER AVAILABLE

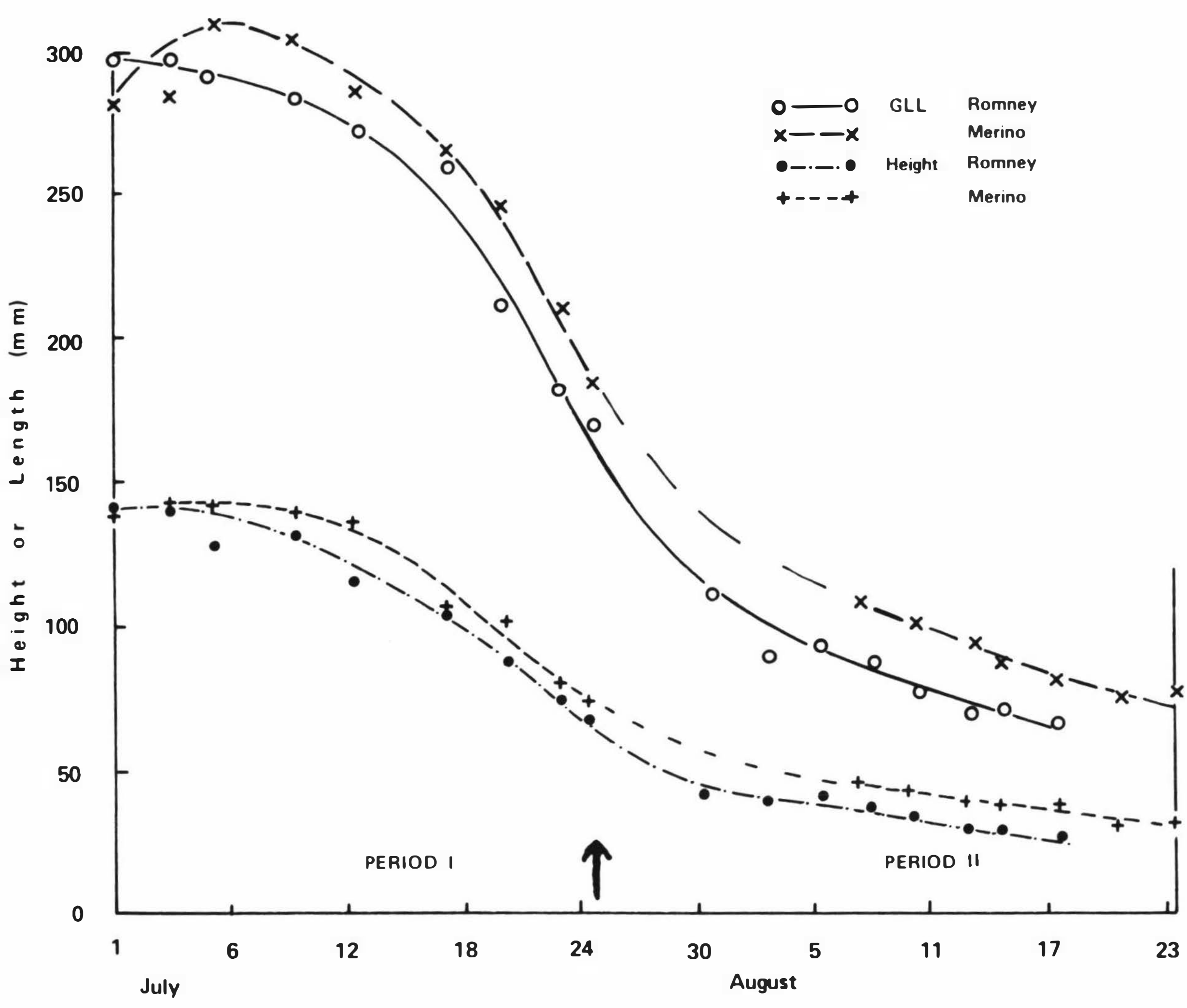

FIG. III. 2 CHANGES IN MEAN HEIGHT AND GREEN LEAF LENGTH (G.L.L.) OF SWARD

Plate 4.

General view of site of Experiment II (upper).
Close-up of merino pasture at commencement of grazing showing patch grazing (lower).

(iii) Botanical Composition:

The botanical composition of the sward was similar under each treatment (Table III.2). The proportion of dead material rose in each treatment during the experiment at the expense of the green cocksfoot. The contaminant species, poa annua, poa trivialis, perennial ryegrass and yorkshire fog, represented a constant proportion of the total dry matter at each sampling.

Table III.2. Botanical Composition (% dry matter).

	Romney			Merino		
Date	Cocksfoot	Other spp.	Dead	Cocksfoot	Other spp.	Dead
30 June	48.4	27.5	24.1	42.9	26.4	30.7
17 July	40.4	28.1	31.5	46.2	28.8	25.0
3 Aug.	35.6	25.4	39.0	34.5	26.9	38.6
14 Aug.	27.8	25.0	47.2	28.1	25.0	46.9

(iv) Tillers Height and Green Leaf Length:

The changes in height and green leaf length of the pastures under each treatment are shown in Fig. III.2 and Table III.3. The rate of change was similar in both treatments with a steady decline in height and G.L.L. being much greater in period I than in period II.

Table III.3. Mean Heights (mm) and Green Leaf Lengths (G.L.L.) of tillers (mm)

	Romney				Merino			
	Height	± S.E.	G.L.L.	± S.E.	Height	± S.E.	G.L.L.	± S.E.
Period I	110.3	9.15	251.8	16.49	118.2	9.18	263.6	14.17
Period II	34.8	1.96	83.5	5.39	39.5	2.31	89.8	4.58
Period I & II	72.6	10.2	172.7	22.79	83.8	11.30	175.8	26.44

(v) Tiller Counts:

The mean cocksfoot tiller densities were somewhat similar in each treatment. However the contribution of contaminant species was greater in the merino treatment than in the romney treatment. Again, for the most part, the tiller size of the contaminant species was small compared with the cocksfoot tillers. Dead tillers were not found after the first observation on 29 June.

The number of live tillers declined over the experiment. This was more marked with cocksfoot than with the contaminant species.

Table III.4. Tiller Counts (number/m^2)

Date	Cocks.	± S.E.	Other spp.	± S.E.	Dead	± S.E.
			Romney			
29 June	5470	767	2360	383	49	35
23 July	3160	565	4240	562	0	-
15 Aug.	3350	540	2080	462	0	-
			Merino			
29 June	4450	843	4400	664	98	68
23 July	2400	480	4700	173	0	-
15 Aug.	3160	570	3900	400	0	-

(vi) Position of Growing Points:

The mean depth of the growing point of the cocksfoot tillers at the commencement of the experiment (29 June) was 8.70 mm below the ground surface (S.E. of mean = 0.511). At this stage no extension of the growing point was observed which was about 2 mm above the root : shoot junction. A further examination was made on the 15th August but as no elongation of the growing point was seen in any of the tillers examined the mean depth of the growing point was not estimated.

Animal Records.

During period I the mean liveweight of the romneys and merinos increased by 3.4 Kgs and 6.1 Kgs respectively. A slight decline in weight occured during period II (Table III.5).

Table III.5. Liveweight Changes (Kgs).

	Romney		Merino	
Date	Mean	± S.E. of mean	Mean	± S.E. of mean
July 4	44.0	0.67	38.4	1.51
July 24	47.4	0.54	44.5	0.69
August 14	46.1	0.94	43.9	0.76

It was interesting to observe that during tiller measurements the merinos grouped together in a small bunch and normally would not graze, whereas the romney were, after a few days, unaffected by the observer and continued to graze normally. One merino wether developed footrot for a short period which may have reduced its grazing time. This occured in spite of careful attention to feet prior to the commencement of the experiment. The field measurements never disturbed the sheep in any one plot for more than 4 hours at a time, every 2.7 - 2.8 days. Any effect on grazing time, if in fact this occured, was probably small.

Loss of Records.

The number of marked tillers surviving at the end of period I was 234 in the romney and 236 in the merino treatment. By the end of period II there were 232 in the romney treatment and 225 in the merino. The losses and how these occured are shown in Table III.6.

During this experiment the losses of records was quite low when compared with experiment I and this is accounted for mainly by the lesser number of displaced tillers. The taller pastures present in this experiment probably accounts for the fewer displaced tillers. Since fewer tillers were observed to be uprooted this also would have influenced the loss of markers.

Table III.6. Reasons for Loss of Tiller Records, and Losses in each Category.

	Romney		Merino	
Period	I	II	I	II
No. tagged	240	240	240	240
Total Lost	6	8	4	15
Uprooted	0	0	0	0
Displaced	1	2	0	0
Death due to complete defoliation	0	1	1	2
Trodden	2	1	1	1
Death from other causes	3	3	2	7

Defoliation of tillers.

(a) Frequency of Defoliation.

Sixteen observations (8 in each period) were made on the romney treatment and fifteen on the merino treatment (8 in period I and 7 in period II). The frequency of defoliation for each period is shown in Table III.7.

Table III.7. Frequency of Defoliation (days between defoliations).

	Romney	± S.E.	Merino	± S.E.
Period I	9.1	0.36	10.9	0.36
Period II	7.1	0.36	7.7	0.36

There was no significant difference between the merino and romney treatments. However the difference between period I and period II was highly significant. There was no significant interaction.

The frequency of defoliation was not significantly different between transects within either treatment or period within a treatment.

Table III.8. Mean G.L.L. and Height (cm) of Grazed and Ungrazed Tillers Before Grazing.

Romney

Date	G.L.L. Grazed	G.L.L. Ungrazed	Sig.	Height Grazed	Height Ungrazed
July 7	31.12	29.26	N.S.	12.15	15.35
10	32.53	27.87	0.10	12.47	20.62
13	30.44	26.55	N.S.	14.42	11.77
17	30.77	25.27	N.S.	12.46	11.33
20	26.68	25.38	N.S.	10.92	10.25
23	21.88	20.16	N.S.	9.11	8.63
25	21.63	17.38	0.10	3.40	6.80
August 3	14.68	3.75	0.10	4.77	3.20
6	9.11	8.89	N.S.	4.62	3.59
8	10.53	9.02	N.S.	4.44	3.66
10	10.08	7.39	N.S.	4.50	3.38
13	8.37	6.99	0.05	3.83	3.25
15	8.38	6.46	0.10	3.78	2.63
18	8.91	6.13	0.05	3.30	2.36
21	7.19	6.38	N.S.	3.15	2.64

Merino

Date	G.L.L. Grazed	G.L.L. Ungrazed	Sig.	Height Grazed	Height Ungrazed
July 7					
10	34.00	30.30	N.S.	15.33	14.13
13	31.76	30.21	N.S.	14.31	13.60
17	31.03	26.13	0.05	13.30	11.55
20	32.56	22.91	0.10	12.00	9.96
23	25.51	23.06	N.S.	10.17	9.52
25	24.48	19.66	N.S.	9.83	7.27
August 10	11.51	9.97	N.S.	5.03	4.74
13	11.18	9.25	N.S.	4.90	4.03
15	10.59	8.97	N.S.	4.00	3.99
18	9.46	8.48	0.05	4.38	4.46
21	8.79	7.93	N.S.	4.20	3.64
24	7.12	7.70	N.S.	3.27	3.44
26	10.27	7.39	N.S.	3.92	3.08

Table III.8. shows the G.L.L. of tillers grazed and not grazed at succeeding observations. At all observations except one in the merino treatment, the G.L.L. of tillers subsequently grazed was greater than that of tillers not subsequently grazed. However these differences only reached significance on 6 occasions on the romney treatment and on 3 occasions in the merino treatments.

The subsequent frequency of defoliation during period I of tillers initially grazed prior to July 10 and those not grazed prior to this date is shown in Table III.9. It can be seen that the differences in the subsequent frequency of defoliation of those tillers initially selected and those not initially selected were not significant in either treatment during period I.

Table III.9. Subsequent Defoliations during period I of Tillers Grazed or Ungrazed prior to July 10.

	Romney		Merino	
	Grazed	Ungrazed	Grazed	Ungrazed
No. tillers	69	171	56	184
No. defoliations	2.35 ± 0.127	2.42 ± 0.094	2.15 ± 0.15	2.05 ± 0.093

(b) Severity of Defoliation.

As in experiment I estimates were made of the severity of defoliation in terms of the mean green leaf length removed per tiller at a defoliation and expressed as a percentage of that available on grazed tillers. The results are shown in Fig. III.3. and Table III.10.

Table III.10. Severity of Defoliation of Individual Tillers in terms of G.L.L. (mm) and as a Percentage of G.L.L. removed (%).

		mm	± S.E.	%	± S.E.
Period I	Romney	68.33	15.05	24.70	2.69
	Merino	65.02	15.05	22.15	2.69
Period II	Romney	29.26	15.05	29.32	2.69
	Merino	29.88	15.05	31.33	2.69
Period I & II	Romney	45.97	10.64	27.34	1.90
	Merino	47.45	10.64	26.74	1.90

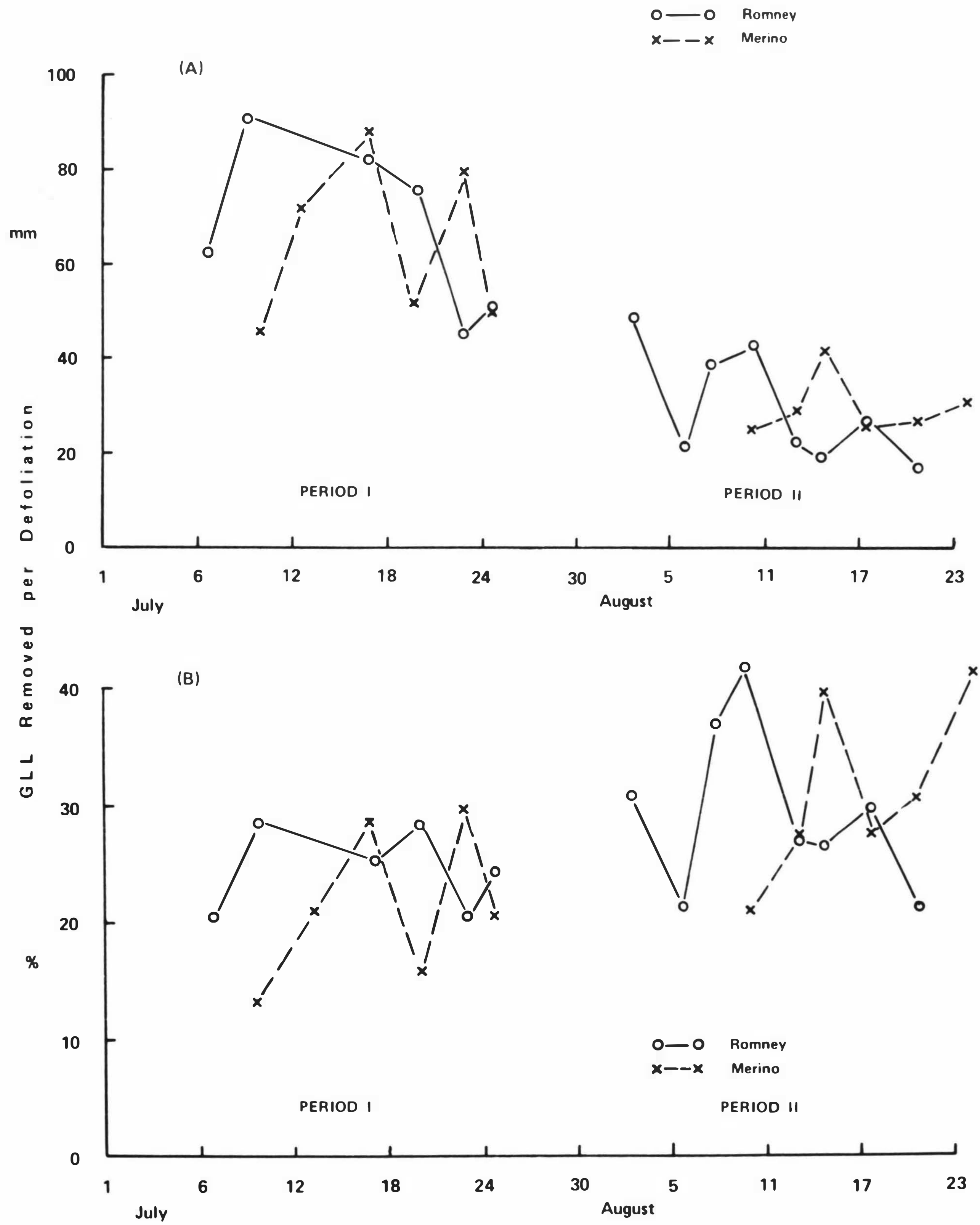

FIG. III. 3 SEVERITY OF DEFOLIATION OF INDIVIDUAL TILLERS

(A) Mean GLL removed (m.m) and (B) % of GLL removed, at a single defoliation.

The length of leaf removed was very similar under both treatments and the small differences within periods were not significant. The differences between periods was significant as a greater G.L.E. was removed on the taller pastures during period I.

In contrast to the length of leaf removed the % removed increased significantly from period I to period II over the whole experiment as the pastures were more closely grazed.

A feature of the graphs shown in Fig. III.3. is the similarity in shape of the length removed and the % removed. This contrasts with a much less distinct relationship observed in experiment I.

(c) Age Categories of Tillers.

Analysis of the two age groups of tillers suggested that the old tillers were defoliated more frequently than the young tillers particularly by the romney wethers during period I. (Table III.11).

All tillers were defoliated more frequently during period II than during period I but there was no interaction with the category of tillers or treatment.

The pattern of severity of defoliation indicates that during period I the old and young tillers were grazed differently. On the romney treatment the young tillers were grazed much less severely than the old tillers but on the merino treatment the converse occured with young tillers being more severely grazed than old tillers. During period II young and old tillers appeared to be grazed with equal severity under both treatments.

(d) Defoliation of Individual Leaves.

The pattern of leaf selection within tillers is shown in Fig. III.4. As in Experiment I there was a definite selection for the younger leaves and against the older leaves, during both periods. The selection pattern is much more marked under the merino treatment than under the romney treatment. In fact there appears to be a gradation from leaf 1, to leaf 2, to older leaves but under the romney treatment the second leaf appears to be selected more frequently than either the first leaf or older leaves. Merino sheep appear to select more against older leaves than do romney sheep.

Table III. 11 (a) Frequency of Defoliation of "Old" and "Young" Tillers (days between defoliations).

	Romney				Merino			
	Old	± S.E.	Young	± S.E.	Old	± S.E.	Young	± S.E.
Period I	8.0*	0.59	11.6	0.59	10.0	0.59	10.9	0.59
Period II	7.2	0.59	8.1	0.59	7.5	0.59	8.4	0.59
Period I & II	7.6+	0.35	9.5	0.35	8.6	0.35	9.5	0.35

* S.E. for period I or period II x category = ± 0.59

\+ S.E. for period I & II x category = ±0.35

(b) Severity of Defoliation of "Old" and "Young" Tillers (% G.L.L. removed per defoliation)

	Romney		Merino	
	Old	Young	Old	Young
Period I	25.39	13.63	23.78	31.11
Period II	30.92	31.56	26.62	29.24

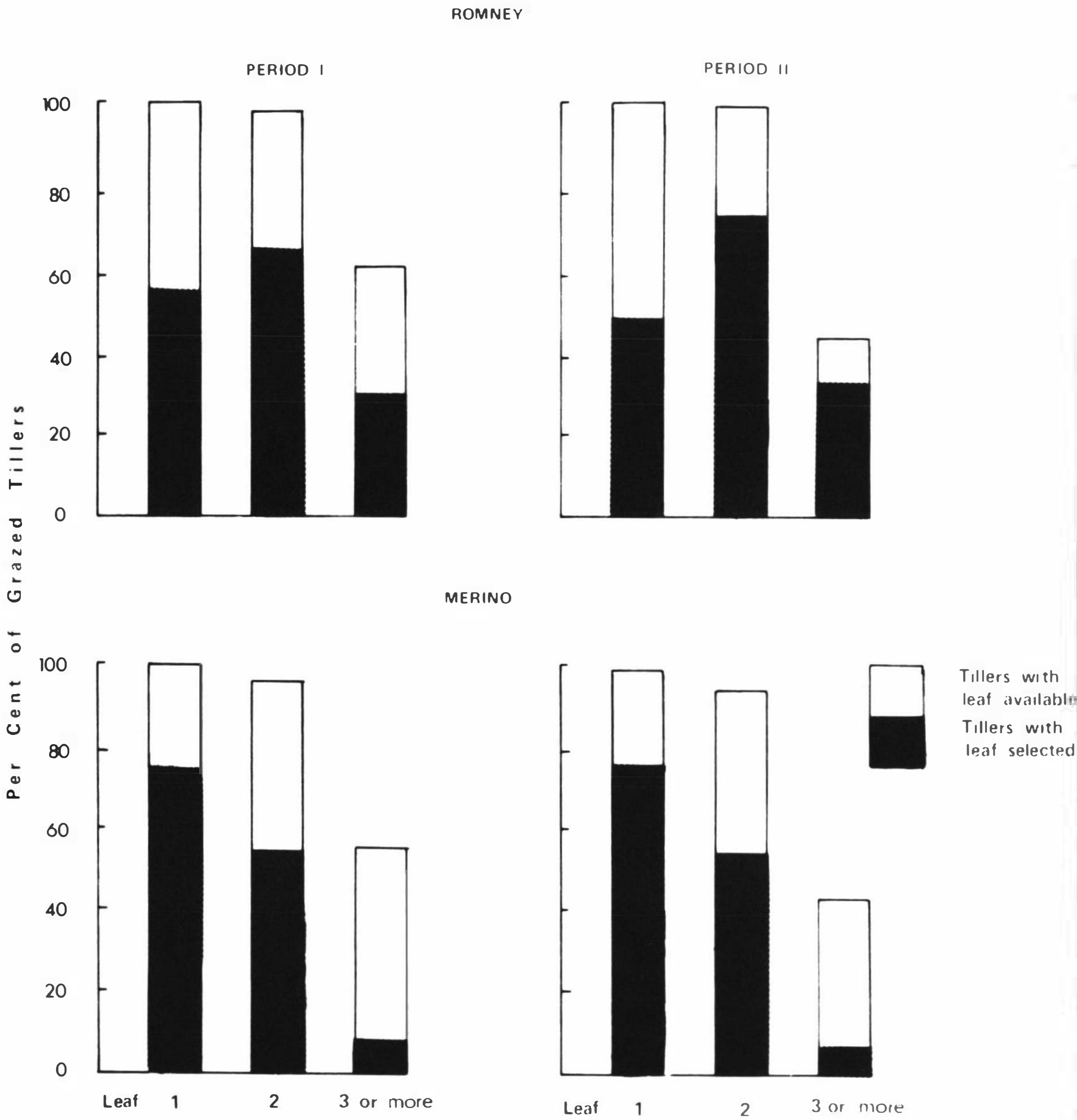

FIG. III. 4 PATTERN OF LEAF SELECTION ON TILLERS

Showing % of tillers with youngest (1), intermediate (2) and oldest (3 or more) leaves available (unshaded) and selected (shaded)

E. Discussion.

(i) Of Techniques:

The main pasture, animal and tillers measurements used did not differ significantly from those used in Experiment I. The only additional measurement made in this experiment was the determination of the depth of the growing point. A few other workers (Branson, 1953; Aitken, 1962; van der Booysen, 1963), have also determined the position of the growing point of grasses in relation to its accessibility to grazing and possible effects on reproductive grasses. The technique used has commonly involved splitting the tiller and examining the position of the apex. This technique is relatively simple when the growing point is above ground level but may involve some difficulty when below ground level. Branson (1953) found the position of the growing point to vary significantly between species. Kentucky bluegrass (*Poa pratensis*) for example had its growing point below ground throughout the entire growing season while Western Wheatgrass (*Agropyron smithii*) presented its growing point as high as 5 inches above ground level, even early in the growing season. The results obtained in this study for cocksfoot are consistent with Branson's data which showed that for perennial grasses the growing point is generally below the soil surface. The technique used in this study is simple and quick (150 tillers were processed in the laboratory in about 2 hours) especially during the vegetative stages of growth. Once internode elongation commences a greater pasture sampling intensity would probably be necessary.

(ii) Of Results:

Pasture Measurements.

The quantity of pasture available declined steadily under each treatment throughout the experiment. At the commencement of the experiment the rate of growth of the pasture was very low and the losses by decomposition of dead material were probably as great or greater, than the new growth due to leaf initiation and expansion. Towards the end of the experimental period the growth rate rose corresponding with the normal start of the spring growth associated with rising temperatures and better light conditions. However the major factor determining the availability decline was removal by the animal. Comparison of the two curves (Fig.III.1) would probably suggest that the rate of intake of the two breeds of sheep, merino and romney, was rather similar.

As the availability declined there was a corresponding reduction in the height of the pasture and alteration in the botanical composition of the total dry matter available. Because dead matter is confined mainly to the base of the sward this made a relatively greater contribution to the total dry matter available as pastures became more closely grazed.

Associated with the seasonal conditions of low temperature there is a decline in tiller numbers due mainly to the very low rate of initiation of new tiller buds (Langer, 1963). This decline may have been accentuated, particularly during period I, due to shading of some tillers in the tall dense swards causing death (Hunt, 1968). Fewer tillers were observed to be uprooted in this experiment compared with Experiment I. This may have been the result of better root development under the wetter soil conditions of July and August than occured under the very dry soil conditions in Experiment I causing tillers to be more firmly anchored. Also since the pastures were not closely grazed in this experiment a critical height at which losses may be maximised may not have been reached.

Contaminant species, mainly poa species, perennial ryegrass and yorkshire fog, represented a significant proportion of the available green matter in each treatment. For the most part these species were scattered evenly through the cocksfoot but a few more concentrated areas were present on the merino plot. These species were unlikely to have had a major effect on the pattern of grazing but they may have contributed to some of the variation in the frequency of defoliation of tillers between transects during period I. The merino sheep were observed to graze the more prostrate contaminants at the beginning of the experiment. The two transects (1 and 2) located in this region had higher frequencies of defoliation during period I (AppendixIII Table 3).

Animals Records.

The weight changes of the sheep were very similar for each breed. They indicate that intake was probably unaffected during period I but during period II some reduction of intake may have occured. The romney plots were very short during period II and the rate of intake may have been limited by this factor. On the merino treatment however, one of the wethers contracted footrot and it was the loss in weight of this animal that caused the merino treatment to show a decline in weight during period II; the other two sheep maintaining weight. The ability of these two sheep to maintain weight under the short conditions may be due to the relatively smaller size of mouth of the merino sheep compared with romney facilitating in the grazing of very short pastures (Allden and Whittaker, 1970).

Tiller Losses.

Very few records were lost in this experiment. Wetter soil conditions rather than leading to greater numbers of lost records as was expected, may enable markers and tillers to be less susceptible to displacement. The differerces observed between this experiment and Experiment I may also be associated with the relative closeness of grazing. Losses became more marked the closer pastures were grazed in experiment I but in this study the pastures were not grazed as close.

Pattern of Defoliation.

(a) Frequency.

Under both treatments frequency of defoliation increased as the pasture height and availability declined. This pattern follows that observed in the medium treatment of Experiment I and agrees with expectations under conditions of declining availability (Morris, 1969). As the animal endeavours to maintain intake rate of biting and the length of time spent grazing increases, this would be reflected in an increased frequency of defoliation of individual tillers.

For the two treatments in this experiment there was a closer relationship in the change in pasture conditions, i.e. height and availability, with the medium stocked treatment in Experiment I rather than with the more extreme high stocked treatment. Though the sheep on the romney treatment lost weight during period II the stage at which a reduction occurs in the frequency of defoliation due to the shortness and reduced availability of the pasture does not appear to have been reached.

(b) Severity of Defoliation.

The pattern of change in G.L.L. removed (mm) seems to follow the same pattern observed in experiment I, being closely related to the changing height and G.L.L. of the pasture. In a similar study on cocksfoot Morris (1969) also found the greatest length of G.L. removed was from the pastures where the G.L.L. of tiller was greatest.

The % G.L.L. removed per defoliation rose from levels of about 23% during period I to 30% during period II for the similar conditions of declining pasture height and G.L.L. These values are lower than those of about 36% and 33% observed in experiment I but again are similar to the pattern observed by Morris for lambs grazing cocksfoot where the severity of defoliation increased from 19 to 30% as the L.A.I. of the pastures declined from 5 to 3 units. The pattern of increased severity of defoliation as pasture height declines agrees with results found in other studies (Hodgson, 1966, 1969) and expectations based on a declining length of G.L. available per tiller before defoliation.

The disparity of these results and experiment I could be due to less marked changes in tiller density of the two pastures during the course of the experiment. A much smaller increase in pasture density as they were grazed closer to ground level in this experiment, would not have allowed the grazing sheep to compensate for the effects of reduced height by increasing the size of bite (Arnold and Dudzinski, 1969). This probably caused them to graze plants more severely as height declined.

It is also likely that the low density of the pastures at the commencement of experiment I contributed to the high severity observed during period I for that experiment. A large bite could only be achieved by removing a large proportion of a few tillers rather than a lesser proportion of a greater number of tillers as probably was possible at the commencement of this present experiment.

Both graphs of severity of defoliation show a more marked saw-toothed pattern with successive observations than was observed in Experiment I. It is also noticeable that the peaks and troughs correspond more closely than was observed in Experiment I. It would be expected that changes in the length of green leaf removed should be reflected in the % of G.L.L. removed since it is not possible for the G.L.L. of tillers to fluctuate widely over short periods of time.

The fluctuations in G.L.L. removed reflect the length of leaf removed per tiller without the correction applied for growth between observation dates. This factor does not appear to correspond consistently with changes in growth rate of the pasture observed from the increases in G.L.L. of ungrazed tillers, although the three low estimates during period I on the merino treatment at July 10, 20 and 25 do correspond with very low values of estimated growth rate. Marked fluctuations in growth as determined by this method were observed during this experiment (Appendix III Table 5). Brougham and Glenday (1969) report fluctuations of up to three times the usual growth rate during the winter season for cocksfoot and ryegrass as a result of weather fluctuations e.g. increases in night temperatures. The fluctuations in growth rate in this study accentuated the fluctuations in the % of G.L.L. removed when the correction for growth rate was applied.

(c) Age Categories of Tillers.

The pattern of frequency of defoliation shows that both breeds grazed the "old" tillers more frequently than the "young" tillers. This pattern may have been due to deliberate selection of either the oldest tillers or against the youngest tillers or to the structure of the two categories of tillers interacting with the sheep's normal grazing process. Table III.12. shows the differences in G.L.L. of the two categories of tillers. The "older" tillers were always larger than the "young" tillers although this was less marked in period II. It appears that the normal horizontal grazing pattern of sheep leads to the tallest and most obvious tillers i.e. the "old" tillers, being grazed more frequently than the less obvious tillers i.e. the "young" tillers. No other differences in their structure or composition were obvious in the

Table III.12. Mean G.L.L. of "Old" and "Young" Tillers (mm)

	Romney		Merino	
	Old	Young	Old	Young
Period I	270.4	205.9	276.8	228.9
Period II	78.3	70.3	91.5	88.5
Period I & II	178.8	138.1	184.2	158.7

field.

However, the pattern of severity of defoliation does not appear to follow the expected pattern of an increased severity with shorter G.L.L. of tillers. During period I the romney sheep grazed the tillers of lesser G.L.L., i.e. the "young" tillers, very lightly compared with "old" tillers. On the other hand the merino sheep did graze the "young" tillers with a greater severity. This difference in pattern could indicate a possible difference in the pattern of grazing of these two breeds. Where the sheep is faced with a mixture of tall and shorter tillers, grazing in a horizontal plane may be more important to the romney breed but for the merino breed this basic process may be modified by a greater degree of selection on the vertical plane as described by Arnold (1960). Thus shorter tillers within a mixture of sizes may be grazed closer to ground level than taller tillers by merino sheep. During period II when the "old" and "young" tillers were more similar in G.L.L. the pattern of severity was similar for each category for both breeds of sheep.

(d) Selection.

(i) Within the Pasture:

The statistical results show that there was very little selection for different sites of the paddock by either merino or romney sheep. All transects appeared to be grazed equally and tillers initially selected were not subsequently grazed more frequently than those not initially selected. However

Plate 5.

Development of the "dung patch" grazing effect on the merino pasture (right side of the fence) after 3 weeks (upper) and after 6 weeks (lower). Note the plainly visible dung on the romney plot (left side of the fence).

observation on the paddocks did indicate that some selection was occuring particularly by the merino sheep. The observations of selection by merinos for sites where contaminant species were concentrated has been referred to. The low relative palatability of cocksfoot (Stapleton et al, 1927) may have accounted for the selection of these areas at the beginning of the experiment. The areas of contaminant species were also shorter than the major part of the pasture which may have made them more attractive to sheep which prefer to graze shorter pastures than longer pastures (Arnold, 1967).

In the merino plots, ungrazed or lightly grazed patches, 30-40 cm in diameter, were observed to develop after about two weeks. These became more distinctive as grazing progressed (Plate 5), although they were grazed more closely and decreased in diameter. These patches corresponded with dung patches on the paddock. By contrast on the romney treatment no discrimination occured and grazing was right up to the dung itself (Plate 5). The development of patches in a pasture because of the localisation of dung patches is a feature often observed in dairy pastures (McLusky, 1960; Marten and Donker, 1964; MacDiarmid, 1969 and others), but no reports appear to have been cited for similar situations in sheep grazed pastures.

In cattle, smell of the faeces has been clearly shown to be the main factor causing the avoidance of dunged areas (MacDiarmid, 1969). In sheep the sense of smell has been shown to affect the selection of forage. Tribe (1949) observed pen-fed cheviot lambs to avoid herbage close to offensive smells whereas similar lambs with their olfactory lobes removed showed no discrimination. Destroying the sense of smell of grazing border-leicester x merino wethers also led to altered species preferences (Arnold, 1967). These results indicate that the smell of the faeces could be the factor in the avoidance of dunged areas in this study. However, the reason for the breed differences is not clear. There is no reason to believe that the sense of smell is any different between the two breeds of sheep. Tribe (1949) noted that smell was only important in the initial selection by grazing sheep and that after a short period the animal adapted to the smell and grazed the offensive material readily. Perhaps romneys adapt more readily to the smell of faeces than do merinos. Because adaptations are involved the previous history of the two groups of animals may also have had some effect on this selection pattern.

(ii) Within Tillers:

The results shown in Fig. III. 4. indicate that merino sheep discriminate against older leaves on a tiller more than romneys. This pattern was more marked during period II when the two pastures were more alike in their physical characteristics. This pattern may reflect a greater ability to select by merino sheep which appear to have a narrower jaw width than the romney sheep. This may allow easy rejection of unpalatable herbage.

Under both treatments the tallest tillers were selected at each defoliation throughout the experiment. This pattern of leaf selection of the tallest tillers also leads to the more frequent defoliation of old tillers in the pasture, particularly during winter, because of their greater height. This selection of the tallest tillers confirms the pattern of horizontal grazing of pastures by sheep (Arnold, 1960).

CHAPTER IV. GENERAL DISCUSSION

Introduction.

In the general discussion the defoliation pattern is discussed according to the different parameters measured in this study. Following this the merino and romney breeds are compared and finally the defoliation pattern is related to grazing behaviour and the grazing process of sheep.

The Pattern of Defoliation of Tillers.

(a) Frequency of defoliation.

The importance of stocking rate in influencing the frequency of defoliation of tillers in a set-stocked sward was first suggested in a theoretical consideration of grazing management by Spedding (1965b). Since that time two investigations have been reported confirming that grazing frequency increases with stocking rate. In the first report (Hodgson, 1966), the indication was of a proportional relationship between frequency and stocking rate. However, a later report indicated that low stocking rates may have frequencies nearly as great as high stocking rates (Hodgson and Ollerenshaw, 1969). The results reported in the experiments in this study also show that the frequency of defoliation of medium stocked swards is only a little less than that of high stocked swards. This leads to the question; Why is frequency of defoliation not proportional to stocking rate? This study shows that one of the factors which can have a big effect in causing the pattern to vary is pasture conditions, in particular the pasture height and/or availability.

It is suggested that the changing frequency of defoliation is a response to changes in grazing behaviour brought about as the pasture declines in availability and height. Height or length of tillers is probably of more importance in causing changes in the rate of biting and time of grazing than the availability (Allden and Whittaker, 1970; Arnold and Dudzinski, 1969). Allden and Whittaker found these two factors commenced to increase as the length of tillers fell below 35 cm. Therefore since the maximum height on any pasture in this study was 15 cm, and the height declined rapidly on all treatments, increases in rate of biting and grazing time are likely to have occurred from the initial stages. Therefore a decline in height of pasture will result in an increase in the frequency of defoliation of tillers even when stocking rate is held constant. Where pastures are grazed to short lengths, e.g. 3 cm. or less, very considerable changes may occur in the grazing behaviour and therefore the frequency of defoliation of tillers. Such heights were reached by Hodgson (1969) on his highest stocked treatment, which together with intake being reduced by 50% on this treatment compared with the low stocked treatment, suggested that his observed pattern of defoliation was probably influenced greatly through changes in grazing behaviour.

However under very difficult pasture conditions, e.g. very short pastures, grazing sheep can only increase the rate of biting and time of grazing up to certain limits. Such limits are probably due to grazing fatigue (McClymont, 1967). In Experiment I, it is felt that the maximum grazing time and maximum rate of biting may have been reached under the high stocked treatment, with the result that grazing frequency and stocking rate may fail to remain proportional beyond such a stage as occured in this treatment during period II.

Pasture height can therefore have a considerable bearing on the observed frequency of defoliation of pastures under different stocking rates. Under moderately short pasture conditions (5 - 6 cm) the frequency of defoliation of individual tillers in a range of stocking rates can be enhanced, but as the pasture becomes shorter the frequency may decline again, both resulting from changes in grazing behaviour. These changes may account for the similarities in frequency of defoliation of pastures where the stocking rates are quite different especially when the pastures under each treatment are moderately short. From these conclusions can be inferred that any consideration of the pattern of frequency of defoliation under different stocking rates should give account to the pasture height under each treatment.

(b) Severity of defoliation.

There is some disagreement between Hodgson (1966, 1969) and Morris (1969) concerning the pattern of change in the severity of defoliation (percentage removed) of individual tillers in a sward in relation to stocking rate and grazing pressure. For example Hodgson has showed an increase in severity (percentage removed) with increasing stocking rate and grazing pressure for perennial ryegrass pastures but Morris using cocksfoot pastures, found no such significant increases. The results obtained from this study are similar to both these workers, in that the results of Experiment I showed no increase in the severity of defoliation with an increase in stocking rate and grazing pressure while the results of Experiment II did show an increase. However from the results of this study the severity of defoliation also appears to be related to the height of the pasture.

In both experiments what is immediately apparent is the similarity in the shape of curves for length of green leaf (mm) removed per defoliation and the curves for the green leaf length of tillers. If it is considered that the G.L.L. (mm) removed is a reflection of the size of bite of grazing sheep (as has been discussed) this pattern fits the expected pattern of a declining size of bite as pasture decreases in tiller length (see Fig. I.1). In other words it appears that the difference in length of leaf removed between stocking rates is due to the difference in initial G.L.L. and not to any stocking rate effect.

Since the length of leaf removed varies closely with the G.L.L. of the tiller before grazing it might be expected that the percentage G.L.L. removed would not vary greatly as the height of pastures changed. This appears to have occured in Experiment I where there was no significant difference between the stocking rates, or periods, nor any interaction between stocking rate and period. The sheep appeared not to remove a greater percentage of the G.L.L. from the tillers as they decreased in height. However in Experiment II the percentage removed did increase significantly as the pasture height declined; although this increase was not large i.e. from 22-24% to 29-31%.

The existence of these two types of response indicate that other factors, besides the relationship between length of leaf removed and initial G.L.L. of tillers may be influencing the percentage of G.L.L. removed. One such factor may have been the growth form of the tillers. As previously mentioned the tillers in Experiment I were observed to change to a more prostrate growth habit during the time of observations, especially in period II. The changes in Experiment II were not so apparent. The development of a more prostrate growth form results in a greater proportion of the leaf tissue being close to ground level. This may mean that a smaller proportion can be readily prehended by the grazing sheep, particularly when pastures are very short, e.g. 2-3 cms. However no information is available for how the severity of defoliation varies with the growth form of tillers. This factor could also be involved in differences observed between the lower severity of defoliation of cocksfoot tillers by Morris, (1969) than of perennial ryegrass tillers by Hodgson (1966, 1969).

(c) Frequency and Intensity of Defoliation of Age Categories of Tillers.

The presence in the pasture of different aged tillers is more marked in some seasons than others. For example in autumn tillering is very active due to the favourable climatic conditions and a high proportion of young tillers can be expected to be present, which rapidly reach a mature size. Conversely in winter tillering is much reduced as conditions for growth decline and, as in Experiment II, there are fewer young tillers present and they remained smaller in size throughout the experiment. These features probably determined the observed pattern of defoliation of different aged tillers in this present study, such that in experiment I during period I "young" tillers rapidly reached similar sizes (G.L.L.) to "old" or established tillers, and both were grazed with similar frequency and severity by the romney sheep at both stocking rates.

By comparison, during period II of Experiment I, where the rate of tillering and new tiller growth was declining, the newly developed, or "youngest" tillers were grazed less frequently on the medium stocked treatment and less severely on the high stocked treatment. A similar pattern is seen in Experiment II with romney sheep, the smaller (by G.L.L.) "young" tillers were grazed less frequently than the "old" or established tillers in both periods. During period I when the differences in the G.L.L.

between the two categories of tillers was greatest the severity of defoliation (percentage removed) was also markedly lower in the "young" tillers.

Since green leaf length of tillers bore a fairly constant relationship to height of tillers in these pastures the tillers of greater size were also more prominent in the sward. When this characteristic is coupled with the horizontal grazing process of sheep (Arnold, 1960) those tillers which are shorter would be expected to be grazed less frequently and probably less severely in a relatively uniform sward. Added to this the "youngest" tillers may have been less accessible during the period II of Experiment I as pasture density increased.

It might be expected that the younger tillers would be more palatable than older tillers because of their ages (Arnold, 1960). However this does not appear to have occured in this study. In Experiment I because of the rapid rate of growth after the dry summer all tillers were probably very similar in palatability. The pattern of grazing of young and old tillers in this study contrasts with the emphasis on young leaves of tillers and against less palatable older leaves. This pattern of leaf selection was for periods of rapid and slow rates of growth and a range of sward structures.

As a consequence of the small young tillers being grazed less severely, they will retain a greater proportion of young photosynthetically active leaves relative to the more severely grazed older leaves. This feature together with a lower frequency of defoliation may alter the relationship between the young and older tillers of the tiller population within the subsequent growth period (Davies, 1969).

(d) Selectivity.

(i) Within the pasture:

The feature which appears to be most marked in this study is selection of the longest, and most prominent arrears of the sward. It should be noted however that these pastures were closely grazed after the first week and cannot be compared with often reported situations where excessive length and variability of pasture allows rank, unattractive herbage to develop (Suckling, 1964; Arnold, 1964). On the pastures in this study where the size of bite was being reduced the tallest tillers were probably the easiest to graze and from which the largest bites could be removed. Together with this selection the pattern may also be produced by the horizontal grazing of sheep on uniform swards, resulting in the removal of tallest tillers first.

In a normal set stocked pasture, where the availability is not declining at a rapid rate as in this study, a pattern of selecting the tallest tillers and areas of the paddock probably aids in maintaining the vigour of the whole pasture. The shorter areas of the pasture with a lower leaf area for photosynthesis would, under this lower defoliation pressure, be permitted to make the necessary growth relative to the taller areas.

(ii) Within the tiller:

Over the range of availabilities and pasture heights in this study it appears that the sheep selected their diet mainly from the two youngest leaves on tillers. Willoughby (1959) suggested that under conditions of reduced availability selectivity is probably restricted, and components consumed in proportion to their availability. This pattern does not appear to occur here where even for closely grazed pasture conditions the degree of selection varied very little from that observed under taller pastures. At any one time tillers usually had one or two leaves present where the ligule had not appeared and these leaves would be capable of expansion into the grazing zone during subsequent rest periods after grazing. Because only such leaves are capable of expansion this may have maintained the selectivity of such leaves on the closely grazed swards.

The ability of grazing sheep to select the youngest leaves on a tiller and avoid the older leaves could affect the rate of loss of dry matter, from set-stocked swards, by death and decomposition. Since leaves are generally ungrazed after they reach position 3 (the third youngest) on the tiller most material in this position or lower horizontally in the sward will die and be lost to the grazing animal under set stocked conditions. This loss could, on the basis of the results of this study, be occuring similarly under short and longer pasture conditions. It is likely to be accentuated during seasons when the rate of leaf initiation and leaf death is very high because leaves will reach positions where grazing is unlikely (e.g. 3) more quickly.

Defoliation Pattern of Romney and Merino Sheep.

The frequency and intensity of defoliation was remarkably similar for the two breeds compared in this experiment. The pattern of change during the experiment appears to follow closely the changing pasture conditions as frequency and severity increases, indicating that in the range of availabilities and heights studied both breeds respond similarly in grazing behaviour and resultant defoliation pattern. An uneven appearance of the merino pastures during the experiment gave the impression that the merinos may be grazing tillers less severely or less frequently but apparently their effects on the pasture are rather similar to romneys. However it is not possible from this study to suggest whether different breeds would react differently under other conditions, such as over different grazing periods, stocking rates and times of the year.

Although the frequency and intensity of defoliation of the two breeds is similar there are indications that the pattern of selectivity may vary. The different aged tillers were grazed in a different way by the romney sheep and merino sheep. Where the romney sheep grazed the "old" or tallest tillers more frequently and severely, the merinos showed rather a reverse pattern; the "young" or shorter tillers were grazed more severely than the taller "old" tillers and the frequencies of defoliation were similar. The pattern exhibited by the romney sheep has been suggested to largely result from the horizontal grazing process with perhaps little evidence of selection on a vertical plane. The pattern of the merino sheep suggests that selection on a vertical plane could still be apparent for this breed even for relatively uniform pastures. Short tillers in the sward are grazed closer to the ground and no less frequently than tall tillers immediately adjacent.

This greater selectivity by the merino sheep is also supported by a greater selection against the older leaves on the tillers than was observed for romney sheep.

Hart (1970) has pointed out that sheep have a very short concentration period for any particular plant. This means that selective grazing could be largely determined by the physical proximity of desired and undesired components. If they are close together the grazing sheep may only have time to get the greater part of its mouthful from the desired component. However Arnold (1964) has found that where very selective grazing on a vertical plane is forced by a high dead matter content of pasture the rate of biting is greatly reduced which may allow the degree or level of selection between components to be increased. If for some reason the selection on a vertical plane in the merino breed is heightened then the facility for distinguishing between desired and undesired components may also be increased; this would allow younger leaves to be selected more precisely in preference to older leaves as was observed.

Greater selectivity of merino sheep is also indicated by the pattern of avoidance of herbage around dung patches. This may equally represent a lesser discrimination by the romney breed, but there is no evidence in the literature to suggest which may be the case. No instances have been sighted however that suggested that sheep did not graze herbage around dung pats in the field although a short-term avoidance of herbage smelling of faeces has been observed (see earlier discussion). Previous history affects selectivity and intake of grazing ruminants (McClymont, 1967) and this factor may have been involved for the two groups of sheep in this study. The romney wethers had been reared on the Massey University sheep farms where pastures were mainly of well managed improved species and selection between components may never have been very important. However the merino wethers had been reared on Marlborough hill country in the South Island where the pastures would comprise a greater proportion of native grasses and weed species (Beggs, 1962). In such an environment selection between components is likely to be very marked (Suckling, 1964). Thus the patterns under each breed may have been a carry-over from these earlier environments. However selectivity between the merino and romney breeds needs to be studied more closely under different pasture conditions to give a satisfactory explanation for the results observed in this Experiment.

The Relationship of Defoliation Pattern to Grazing Behaviour and the Grazing Process of Sheep.

The influence of grazing behaviour on the defoliation pattern by grazing sheep has recently been emphasized by Allden and Whittaker (1970). The findings in the present study support these proposals and especially their conclusions "that the frequency and intensity of removal of plant material reaches its highest rate when herbage is in short supply and is at a minimum where there is an abundance of herbage." However this study also shows that some modifications may occur at very low availabilities, where the frequency and intensity may decline probably due to adaptations or adjustments in grazing behaviour and perhaps to changes in the growth form of the pasture.

While grazing behaviour and defoliation pattern are probably closely linked it should be realised that the relationship of these two factors to pasture height and availability may vary depending particularly on the density of pasture. On typical Australian pastures where most grazing behaviour studies have been carried out the sheep may start to adapt the rate of biting and grazing time while pastures are still quite tall (see Fig. I.1) due to the low density. On more dense swards, typical of New Zealand and the United Kingdom, the size of bite is probably maintained until lower heights are reached. Therefore the pattern of defoliation, in particular frequency, may start to alter at a greater pasture height in low density swards than in high density swards. The very high frequency of defoliation on the high stocked treatment during period I probably resulted from rapid changes in behaviour on a sward low in density, because of drought effects over the preceding summer.

The defoliation pattern observed on the present dense swards indicates the importance of grazing in a horizontal plane on such pastures. The mean percentage of G.L.L. removed (ranging from 22% to 36%) was such that complete defoliation of any tillers at a single grazing rarely occured. Rather pastures were gradually grazed more closely to the ground from the top of the canopy and were not eaten off at ground level.

While the sheep grazed mainly in the horizontal direction this did appear to be in patches. This patch effect, which is probably typical of sheep (Stapleton, 1948; Morris, 1969), was especially marked in the early stages on the merino plots where the grazed areas appeared as definite indentations in the canopy (see Plate 4). The method of location of 6 clumps of tillers randomly to each of 10 transects located randomly, was not suitable to detect this patch grazing effect and so the reasons for the selection of these sites could not be related to the measured pasture factors. It is probable that under low stocking rates it is these sites that may be the object of continued grazing while adjacent ungrazed areas become more rank and unacceptable as occured in the study which led to the present comparison of the merino and romney breeds. In that study the merino were stocked at 32 sheep /hectare (compared with 46.2 /hectare in this study) and the grazing period also extended to the time of active spring growth.

Arnold (1960) states that sheep graze on the horizontal plane and select on the vertical plane. Selection appears to occur in this study where the youngest leaves of individual tillers are preferentially selected, but this may be influenced by the denseness of the swards and their growth form. The merino breed may exhibit a greater selectivity on a vertical plane in such pastures than the romney breed (see previous section).

SUMMARY

In this thesis the defoliation pattern of sheep was examined first at a medium and a high stocking rate (36.1 and 79.7 sheep/hectare) using romney sheep and second between the merino and romney breeds of sheep (at 44.4 sheep/hectare). Both experiments were conducted on cocksfoot (*Dactylis glomerata* L) swards where the availability of pasture declined from high levels initially 1500 to 2500 Kgs/hectare to lower levels of 400 to 1000 Kgs/hectare. The heights of pasture also declined from 10 to 15 cm to 1 to 2 cm. The first experiment was carried out in the autumn season and the second in the winter season.

The frequency and severity of defoliation of all tillers, and age categories, was compared.

Tillers were defoliated every 5 days under the high stocked treatment, but the frequency declined to every 6.9 days under very short pasture conditions. Under the medium stocked treatment the frequency of defoliation increased slightly from 8.1 days between grazing to 7.7 days; the decline in height of this sward was not so severe.

The length of G.L.L. (mm) removed per tiller at a defoliation declined as the height and G.L.L. of the tillers declined. The mean percentage of G.L.L. removed was 33% on the medium stocked treatment and 37% on the high stocked treatment. This percentage did not change significantly with changes in the height of the pasture. Under both treatments new tillers produced early in the experiment were grazed with similar frequency and intensity to established tillers, but new tillers produced during the later stages of the experiment were grazed less frequently on the medium stocked treatment and less severely on the high stocked treatment. By contrast younger leaves were preferred over older leaves at all times in both treatments.

Merino and romney sheep grazed tillers with a very similar frequency and severity of defoliation. Romney sheep grazed established tillers more severely than young tillers while merinos grazed young tillers more severely than established tillers. Romney sheep also grazed established tillers more frequently than

young tillers but merinos grazed young tillers just as frequently as established tillers. When the pastures declined in height established and new tillers were grazed with similar frequency and severity.

A characteristic of the merino grazed paddock was the development of a dung patch grazing effect typical of dairy pastures. This was not observed on the romney paddock.

Pasture factors such as height and density were important in determining the defoliation pattern. These factors together with the influence of grazing behaviour on the defoliation pattern are discussed.

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APPENDIX I

Meteorological Data for "Grasslands" D.S.I.R., Palmerston North.

	temperature					rainfall		
	Mean Max. °C	Mean Min. °C	Mean °C	Max Abs. °C	Min Abs. °C	Centi-metres	No of days	30 yrs avge 1928-1960
1969								
May	14.6	7.9	11.3	20.0	0.8	99.6	14	88.9
June	11.6	3.0	7.3	15.7	-2.6	51.8	13	99.1
July	11.0	3.0	7.0	13.9	-2.2	39.1	10	78.7
August	12.9	5.8	9.4	16.2	-1.2	63.8	18	88.9
Sept.	16.5	8.1	12.3	20.0	3.0	32.8	11	73.7
Oct.	15.5	7.2	11.4	19.1	-1.6	37.3	13	96.5
Nov.	20.3	10.5	15.4	24.8	2.2	33.2	7	83.8
Dec.	22.8	13.7	18.3	28.2	8.4	92.7	13	83.8
1970								
Jan.	24.2	14.9	19.6	29.0	8.5	27.4	8	76.2
Febr.	22.8	13.1	18.0	27.4	9.0	8.9	6	76.2
March	23.2	13.1	18.1	29.0	5.9	83.0	15	61.0
April	19.0	10.6	14.8	23.7	3.8	24.6	11	83.8
May	14.4	6.0	10.4	21.6	-1.4	98.0	14	88.9
June	13.2	5.3	9.3	17.4	-0.6	119.6	15	99.1
July	12.8	5.6	9.2	16.0	-1.1	114.5	16	78.7
August	13.7	5.5	9.6	18.8	-1.6	70.4	13	88.9
Sept.	15.3	8.0	11.6	20.7	1.3	165.1	18	73.7

APPENDIX II

Table 1. Summary of Observation Dates for Experiment I.

High Treatment		Low Treatment	
Date of Observation	Interval (days)	Date of Observation	Interval (days)
March 31	Commencement of Experiment		
April 3	3	April 4	4
" 7	4	" 8	4
" 9	2		
" 11	2	" 11	3
" 13	2	" 14	3
" 15	2	" 17	3
" 18	2		
" 20	2	" 20	3
" 22	2	" 23	3
Mean Interval Period I	2.67	Mean Interval Period I	3.3
April 25	3	April 27	4
" 28	3		
" 30	2	" 30	3
May 2	2		
" 5	3	May 4	4
" 9	4	" 7	3
" 11	2	" 9	2
		" 13	4
Mean Interval Period II	2.7	Mean Interval Period II	3.0

APPENDIX

Table 2. Availability Data (Kgs/hectare)

Plot	Medium		High	
	1	2	1	2
31 March	1723 ± 119.9	1473 ± 85.1	1561 ± 78.5	1386 ± 31.4
8 April	3963 ± 119.6	2711 ± 147.9	4640.9 ± 160.6	2257 ± 245.1
15 April	1701 ± 155.2	1728 ± 139.5	1385 ± 187.5	947 ± 120.0
23 April	2700 ± 81.7	2462 ± 169.3	1023 ± 82.5	1267 ± 109.8
30 April	2494 ± 288.7	2448 ± 159.3	966 ± 238.3	1088 ± 118.3
7 May	3101 ± 174.7	1785 ± 81.4	426 ± 69.9	457 ± 13.5
14 May	884 ± 120.4	1019 ± 72.9	381 ± 58.7	336 ± 32.1

Table 2A. Growth Rate (Kgs/hectare/day).

Plot	Medium		High	
	1	2	1	2
30 March – 15 April	+ 58.9	+ 78.4	+ 90.6	+ 85.1
15 April – 30 April	+ 40.2	+ 27.8	+ 32.3	+ 70.8
30 April – 14 May	+ 6.32	+ 50.56	– 4.74	+ 4.70

Table 3. Mean tiller* and clump+ heights at each observation date. (cms)

		March 31	April 8	11.	14.	17.	20.	23.	27.	30.	May 4	7.	9.	13.	14.
Medium Stocked	**Plot 1**														
	tiller	5.82	8.30	6.37	6.50	4.27	4.25	3.58	3.78	3.37	2.57	2.13	2.37	1.90	
	clump	6.4				4.9									2.4
	Plot 2														
	tiller	7.68	10.42	7.05	6.62	6.22	4.95	4.42	3.30	3.10	2.45	2.23	2.00	2.08	
	clump	7.2				6.5									2.3

		March 31	April 3	7	9	11	13	15	18	20	22	25	28	30	May 2	5	9	11	14
High Stocked	**Plot 1**																		
	tiller	5.72	6.90	6.70	3.60	2.62	1.87	1.66	1.78	1.65	1.32	1.18	1.17	1.27	1.30	1.13	1.07	1.07	
	clump	6.1						2.6											1.0
	Plot 2																		
	tiller	7.63	7.47	6.73	4.03	2.83	2.53	2.05	2.18	2.13	1.77	1.43	1.32	1.30	1.18	1.03	1.13	1.00	
	clump	7.2						2.1											1.1

* mean of 3 transects

+ mean of 10 transects

Table 3 A. Mean Clump Height of Pasture (cms).

High Stocked

Plot 1	30 March	16 April	14 May	Plot 2	30 March	16 April	14 May
Transect 1	6.0	2.2	1.1		6.6.	2.4	0.9
2	6.6	2.8	1.3		6.0	2.2	1.1
3	3.8	1.8	0.8		8.2	2.6	1.3
4	6.6	2.8	1.2		8.0	3.4	1.5
5	5.4	2.2	0.8		7.8	1.6	0.8
6	6.8	2.2	1.0		6.8	1.8	0.8
7	5.8	2.0	1.0		6.0	1.4	1.2
8	6.2	2.6	0.9		8.0	1.4	1.0
9	6.6	3.8	1.2		7.8	2.0	1.1
10	6.8	2.8	1.0		7.0	1.8	1.1

Medium Stocked

Plot 1	30 March	16 April	14 May	Plot 2	30 March	16 April	14 May
Transect 1	5.2	4.8	2.2		8.0	6.4	2.2
2	6.1	4.8	2.0		6.2	5.6	2.4
3	7.8	6.4	2.6		7.6	8.0	2.6
4	7.2	4.6	2.4		6.4	9.6	2.8
5	6.8	4.6	2.8		8.6	8.6	2.8
6	6.2	3.6	2.4		6.8	4.0	1.8
7	6.2	5.2	2.4		9.0	6.4	2.0
8	6.4	4.4	2.2		5.8	5.8	2.0
9	5.2	5.8	2.4		6.8	4.4	1.7
10	6.6	4.8	2.8		6.8	6.0	2.4

Table 4. Tiller Counts (tillers/m^2)

Medium Stocked												
Plot 1	Cocks	±S.E.	Other Spp	±S.E.	Dead	±S.E.	Plot 2 Cocks	±S.E.	Other Spp	±S.E.	Dead	±S.E.
29 March	5651	623.1	683	234.5	755	201.5	5029	490.8	2581	288.8	31	9.4
25 April	8678	810.4	1225	338.4	530	121.1	6170	690.4	2468	531.9	428	107.0
12 May	12291	981.4	1683	237.4	92	42.9	9710	1123.4	4957	906.0	71	41.1

High Stocked												
Plot 1	Cocks	±S.E.	Other Spp	±S.E.	Dead	±S.E.	Plot 2 Cocks	±S.E.	Other Spp	±S.E.	Dead	±S.E.
29 March	6640	639.3	734	215.4	224	101.3	4651	494.7	2132	527.6	326	107.9
25 April	6395	623.5	1663	445.6	490	128.0	5814	860.1	3397	617.7	347	98.7
12 May	7436	998.7	3223	637.1	357	108.1	6783	882.5	4519	740.5	0	-

Table 5. Uprooted Tillers (number per m^2)

	Medium Stocked						High Stocked					
	Plot 1			Plot 2			Plot 1			Plot 2		
Date	Cocks.	Other Spp.	Dd.	Cocks.	Other Spp.	Dd.	Cocks.	Other Spp.	Dd.	Cocks.	Other Spp.	Dd.
April												
15	60.9	46.0	9.1	62.3	52.4	10.4	3.8	2.0	6.7	16.6	8.6	3.8
18	145.0	54.8	16.1	151.4	29.0	19.3	32.2	0	0	32.0	25.8	0
21	180.4	19.3	25.8	83.8	41.9	41.9	19.3	3.2	0	32.0	12.9	0
25	261.0	77.3	67.7	180.4	38.7	70.9	83.8	16.0	41.9	67.7	66.7	0
28	96.7	19.3	25.8	48.3	119.2	38.7	70.9	9.7	12.9	106.3	70.9	6.4
May												
1	58.0	64.4	9.7	55.6	61.2	22.6	45.1	41.9	12.9	74.1	70.9	6.4
4	116.0	70.9	16.1	80.6	51.6	25.8	83.8	64.4	9.7	177.2	148.2	25.8
9	99.9	38.7	0	48.3	77.3	77.3	51.6	48.3	35.4	122.4	154.7	12.9
12	35.4	25.8	0	9.7	51.6	0	77.3	6.4	6.4	51.6	80.6	0

Table 6. Grazing Times (hours/day)

	Medium Stocked			High Stocked		
	No. records	hrs/day	± S.E.	No. records	hrs/day	± S.E.
March 30-April 6	7	6.8	0.71	14	7.1	0.62
April 7-15	13	7.7	0.42	15	10.5	0.46
April 15-24	6	8.6	0.46	16	10.1	0.46
April 24-May 2	16	9.1	0.32	19	9.1	0.29
May 3-11	17	9.5	0.41	14	9.8	0.33

Table 7. Loss of Tiller Records.

Medium Stocked.

Plot 1	Period I				Period II				Plot 2 Period I				Period II			
	R*	W	B	O	R	W	B	O	R	W	B	O	R	W	B	O
Transect 1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	-
2	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-
3	-	-	1	-	-	-	-	1	-	-	-	1	2	-	1	-
4	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-
5	1	-	1	1	-	-	-	-	-	-	-	-	1	-	-	-
6	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
7	-	-	1	-	-	-	-	-	-	-	-	-	2	1	-	-
8	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1
9	-	-	1	-	-	-	-	1	-	-	1	-	-	-	-	-
10	1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-

High Stocked.

Plot 1	Period I				Period II				Plot 2 Period I				Period II			
	R	W	B	O	R	W	B	O	R	W	B	O	R	W	B	O
Transect 1	-	1	-	1	1	1	3	3	1	1	-	-	2	2	3	2
2	-	-	-	2	-	1	3	2	2	2	1	1	4	1	-	1
3	-	-	-	-	-	-	1	-	1	-	-	2	2	1	2	1
4	-	-	-	-	2	1	1	-	1	1	-	1	2	2	1	5
5	-	-	-	1	2	2	2	1	-	1	1	-	1	1	-	1
6	1	1	1	1	2	3	2	-	2	1	-	-	4	1	1	-
7	2	2	1	2	1	3	2	1	-	-	-	-	2	1	1	1
8	1	-	2	3	-	1	-	1	-	-	1	-	3	2	-	1
9	-	1	-	1	1	1	-	2	1	-	-	2	1	-	-	2
10	1	1	-	2	3	5	2	2	-	-	1	-	1	-	-	1

* R = red, W = white, B = blue, O = orange

Analysis of Variances

Source of Variation	Sums of squares corrected	D.f.	Mean Square	F.	P.
Replication	0.01	1	0.01	0.02	N.S.
Treatment	57.80	1	57.80	92.23	**
Rep. x Tre. (E_1)	0.62	1	0.62		
Transect	2.69	9	0.30	0.22	N.S.
Trans. x Tre.	5.01	9	0.56	0.41	N.S.
Trans. x Tre. x Rep. (E_2)	24.81	18	1.38		
Colour	1.98	3	0.66	1.61	N.S.
Col. x Tre.	0.40	3	0.13	0.32	N.S.
Error 3	47.12	114	0.41		
Period	14.45	1	14.45	25.35	**
Per. x Col.	1.92	3	0.64	1.12	N.S.
Per. x Tre.	8.45	1	8.45	14.83	**
Per. x Trans.	6.11	9	0.68	1.19	N.S.
Per. x Trans. x Tre. x Rep.	8.35	9	0.93	1.63	N.S.
Error 4	79.22	139	0.57		
Total	261	319			

Treatment High (80) > Medium (16)

Period Period II (64) > Period I (32).

Period x Treatment L.S.D. = 27 (5%)

High - period II (54) > High - period I (26)
low - period I (6)
low - period II (10)

Table 8. Frequency of Defoliation of all tillers (no. defoliations /15 days).

Medium Stocked.

	Period I.										Period II.									
Transect	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Plot 1	2.04*	1.52	2.04	1.86	1.94	1.91	1.84	1.89	1.92	1.73	1.98	1.86	2.14	2.03	1.96	1.96	1.93	2.14	2.02	1.96
Plot 2	1.80	1.87	1.60	1.73	1.52	2.04	1.87	1.49	2.07	2.27	2.56	2.11	1.78	2.14	1.34	1.79	1.74	2.21	1.85	1.80

High Stocked.

Plot 1	2.82	3.30	2.76	2.70	3.00	3.19	2.97	3.19	2.98	2.98	1.92	2.39	1.88	1.62	1.94	2.27	2.12	1.87	2.26	2.56
Plot 2	3.09	3.29	2.76	3.02	3.02	2.91	3.09	3.31	2.98	2.76	1.64	2.34	2.06	2.09	2.00	2.25	2.37	2.60	2.51	2.58

* Each figure derived by calculating the mean frequency of tillers (within a clump) having completed records throughout the experiment. Because of lost tillers no estimates could be made for some clumps so transect means were calculated from clump means. Clump means were calculated where 2 or more completed tiller records were present.

Analysis of Variance

Source of Variation	Sums of squares corrected	D.f.	Mean square	F.	P.
Replication	0. 009	1	0. 009	0.1	N.S.
Treatment	9.173	1	9.173	77.1	N.S.
Rep. x Tre. E_1	0.119	1	0.119		
Transect	0.645	9	0.072	1.2	N.S.
Trans. x Tre.	0.860	9	0.096	1.6	N.S.
Trans. x Rep.	0.310	9	0.03	0.5	N.S.
Trans. x Tre. x Rep. E_2	0.510	9	0.06		
Period	2.646	1	2.646	139.3	***
Per. x Tre.	4.585	1	4.585	241.3	***
Per. x Trans.	0.167	9	0.019	1.0	N.S.
Error 3	1.518	29	0.019		
Total	20.633	79			

Period.

Period I 2.43

Period II 2.06

period I period II.

Period x Treatment.

L.S.D. = 0.114 (5%)

High period I (3.01) High period II (2.16)

Low period I (1.85) and II (1.96)

High period II (2.16) Low period I and II

Transect x Treatment x Plot.

Using Duncan's Multiple Range Test.

High plot 2 transect 2 (2.82) transect 3 (2.41)

transect 4 (2.56)

Medium plot 2 transect 1 (2.18), transect 10 (2.05)

transect 5 (1.43)

Table 9. Frequency of defoliation of individual tillers with records complete during Periods I and II (mean no. defoliations per 15 days).

Medium Stocked.

Transect	1	2	3	4	5	6	7	8	9	10
Block 1	2.12	1.81	2.19	2.12	2.12	2.05	1.98	2.12	2.09	2.05
Block 2	2.33	2.23	1.98	1.98	1.64	2.16	1.91	2.02	2.02	2.19

High Stocked.

Block 1	2.74	2.99	2.59	2.52	2.85	2.77	2.74	2.70	2.74	2.96
Block 2	2.63	2.55	2.66	2.70	2.74	2.99	2.88	2.74	2.92	2.66

Analysis of Variance

Source of variation	Sums of squares corrected	D.f.	Mean square	F.	P.
Replication	0.0	1	0		N.S.
Treatment	4.95	1	4.95	4.95	*
Rep. x Tre. (E_1)	0.01	1	0.01		
Transect	0.06	9	0.01	0.25	N.S.
Trans. x Tre.	0.27	9	0.03	0.75	N.S.
Trans. x Rep.	0.13	9	0.01	0.25	N.S.
E_2	0.32	9	0.04		
Total	5.75	39			

Treatment. High (2.76) > Medium (2.06).

Table 10. Frequency of Defoliation of "Old" and "Young" Tillers during period I (no. defoliations /15 days).

	Medium Stocked		High Stocked.	
	Old	Young	Old	Young
Transect 1	1.89	1.83	3.52	2.86
2	1.87	2.48	2.25	3.41
3	1.70	1.79	2.87	2.95
4	1.70	2.22	3.15	3.24
5	1.63	1.83	3.10	3.55
6	2.28	1.96	3.13	3.14
7	2.02	1.70	3.46	2.86
8	1.57	1.70	3.46	3.41
9	2.22	1.71	3.26	2.73
10	2.15	2.48	2.92	3.00

Analysis of Variance.

Source of variation	Sums of squares corrected	D.f.	Mean square	F.	P.
Replication	0.27	9	0.03	0.23	N.S.
Treatment	13.85	1	13.85	106.5	***
Rep. x Tre. (E_1)	1.21	9	0.13		
Category	0.01	1	0.01	0.03	N.S.
Cat. x Rep.	1.65	9	0.18	6.00	*
Cat. x Tre.	0.35	1	0.35	1.17	N.S.
Cat. x Tre. x Rep.E_2	2.81	9	0.30		
Total	20.15	39			

Table 11. Frequency of Defoliation of "Old", "Young" and "Youngest" Tillers during period II (no. defoliations /15 days).

	Medium Stocked			High Stocked		
	Old	Young	Youngest	Old	Young	Youngest
Transect 1	2.55	3.15	1.50	1.78	1.84	1.84
2	2.55	2.10	1.13	2.53	2.76	2.37
3	2.25	2.10	1.35	2.21	2.10	2.89
4	2.63	1.95	2.19	2.45	2.68	1.78
5	1.80	1.50	0.94	2.25	1.78	2.17
6	2.18	2.06	0.94	2.53	2.53	2.37
7	2.40	1.95	1.31	2.53	1.16	1.78
8	2.15	2.06	1.88	2.53	2.96	3.43
9	1.80	2.50	2.25	2.53	3.55	2.17
10	2.10	2.40	0.75	2.53	3.16	2.89

Analysis of Variance

Source of variation	Sums of Squares (corrected)	D.f.	Mean Square	F.	P.
Replication	3.15	9	3.15	0.97	N.S.
Treatment	3.11	1	3.11	7.97	*
Rep. x Tre. (E_1)	3.52	9	0.39		
Categories	2.32	2	1.16	9.67	**
Cat. x Rep.	3.62	18	0.20	1.62	N.S.
Cat. x Tre.	2.34	2	1.17	9.75	**
Cat. x Tre. x Rep.(E_2)	2.22	18	0.12		
Total	20.28	59			

Categories L.S.D. = 0.31 (1%)
Old (2.31) and Young (2.32) > Youngest (1.90).

Categories x Treatment L.S.D. = 1.03 (5%)
High - young (2.45) > low youngest (1.42).

Table 13. Severity of Defoliation (mm removed per defoliation and % removed per defoliation).

Medium Stocked.

Period I	Measured difference in G.L.L.	Correction*	mm G.L.L. removed	% G.L.L. removed
April 8-11	13.35	1.11	14.46	41.3
11-14	10.15	1.89	12.04	43.0
14-17	8.82	1.00	9.82	43.4
17-20	4.31	1.00	5.31	30.3
20-23	3.55	0.15	3.70	24.8
Period II				
April 23-27	1.12	2.80	3.92	29.3
April 27-May 1	3.59	0.68	4.27	31.0
May 1- 4	2.52	0.60	3.12	29.5
4- 7	3.02	0.90	3.92	38.7
7- 9	1.46	0.10	1.56	18.3
9-12	2.61	0.60	3.21	36.6
High Stocked.				
Period I				
March 30-April 3	4.25	1.92	6.17	32.0
April 3- 7	5.61	3.29	8.90	41.8
7- 9	6.25	0	6.25	34.0
9-11	4.54	0	4.54	34.9
11-13	3.32	0	3.32	36.4
13-15	1.92	0	1.92	29.7
15-18	0.31	1.46	1.77	35.2
18-20	1.67	0.18	1.85	30.8
20-22	2.06	0.96	3.02	57.2
Period II				
April 22-25	1.74	0.54	2.28	53.4
25-28	- 0.47	1.98	1.51	41.1
28-30	1.34	0.30	1.64	33.9
April 30-May 2	1.52	0.66	2.18	39.1
May 2- 5	1.71	0.30	2.01	38.6
5- 9	0.97	0.10	1.07	23.9
9-11	0.89	0.40	1.29	28.7

* Mean increase in G.L.L. of ungrazed tillers over observation interval.

Analysis of Variance (mm removed)

Source of Variation	Sums of Squares corrected	D.f.	Mean Square	F.	P.
Treatment	4838	1	4838	8.48	**
Period	6675	1	6675	11.70	**
Tre x Per.	4005	1	4005	7.02	*
Error	12553	23	570.59		
Total	28071	26			

Treatment. Medium (58.38) > High (31.14)

Period. Period I (58.54) > Period II (24.68)

Treatment x Period. L.S.D. = 27.48 (5%)

Medium Period I (89.44) > High Period I (41.93), High Period II (17.28), Medium Period II (35.33).

High Period I (41.93) > High Period II (17.28)

Therefore medium significantly greater than high treatment during period I but not during period II.

Analysis of Variance ([illegible] removed).

Source of Variation	Sums of Squares corrected	D.f.	Mean Square	F.	P.
Treatment	76	1	76	1.04	N.S.
Period	42	1	42	0.57	N.S.
Tre. x Per.	56	1	56	0.77	N.S.
Error	1683	23	73.2		
Total	1857	26			

APPENDIX III.

Table 1. Summary of Observation Dates for Experiment II.

Romney		Merino	
Date of Observation	Interval (days)	Date of Observation	Interval (days)
July 1	Commencement of Experiment		
3	2	July 3	2
7	4	7	4
10	3	10	3
13	3	13	3
		Off for 16th due to wet conditions	
17	3	17	3
20	3	20	3
23	3	23	3
25	2	25	2
	Mean Interval 2.9 days		Mean Interval 2.9 days
August 1			
3	2		
6	3		
8	2	August 7	
10	2	10	3
13	3	13	3
15	2	15	2
18	3	18	3
21	3	21	3
		24	3
		26	2
	Mean Interval 2.5 days		Mean Interval 2.7 days

Table 2. Availability Data. (Kgs/hectare).

	Romney		Merino	
Date	Mean	± S.E. of Mean	Mean	± S.E. of Mean
June 29	2275	156.4	2395	127.8
July 7	1740	100.0	2095	187.0
17	1563	110.0	1888	98.7
24	1344	83.0	1536	110.0
31	1367	19.4	1736	132.4
August 7	1048	110.1	1365	169.4
14	933	144.7	1279	139.2
26			925	90.1

Table 3. Frequency of Defoliation (Mean no. defoliations per 15 days).

Romney. Period I.										
Transect	1	2	3	4	5	6	7	8	9	10
Clump 1	1.50*	1.55	1.80	1.30	1.05	2.10	1.95	1.80	2.40	2.10
2	1.50	0.75	1.50	1.65	1.50	2.40	1.50	1.65	1.50	1.30
3	1.50	0.90	1.95	0.90	1.80	1.35	0.90	1.65	1.50	1.65
4	1.30	0.90	1.20	1.95	1.65	2.10	2.70	1.95	1.05	1.65
5	1.95	1.80	2.40	1.30	1.05	1.50	1.35	2.55	1.95	1.90
6	1.30	1.65	1.35	1.35	1.65	1.65	1.30	2.25	1.30	0.90
Mean	1.67	1.23	1.70	1.58	1.45	1.85	1.70	1.98	1.70	1.67
Merino. Period I .										
Clump 1	2.70	2.40	1.30	0.0	1.35	1.20	1.05	1.20	1.50	0.90
2	1.80	1.50	1.50	0.60	1.65	2.10	1.20	1.65	1.65	1.50
3	0.75	1.65	0.75	1.20	1.95	2.40	1.50	1.20	1.65	1.65
4	1.50	2.25	1.95	1.50	1.05	0.30	1.20	0.0	1.80	0.75
5	2.25	2.25	1.50	1.05	1.50	0.60	1.65	0.90	0.60	1.05
6	2.25	1.95	1.35	1.35	1.20	1.35	0.60	1.20	1.20	0.45
Mean	1.86	2.00	1.48	0.95	1.45	1.33	1.20	1.03	1.40	1.05

* Each figure calculated as mean of records of 4 tillers within a clump.

Table 3. (cont'd)

Romney. Period II.										
Transect	1	2	3	4	5	6	7	8	9	10
Clump 1	2.33	2.69	0.90	1.62	2.87	3.23	3.23	1.62	1.97	2.33
2	2.33	2.33	1.80	1.62	1.43	2.69	1.25	1.25	1.97	1.80
3	1.62	2.69	1.97	2.69	1.07	2.69	1.97	2.15	2.15	3.40
4	2.33	1.97	1.62	2.33	2.15	2.15	2.51	1.80	1.80	2.15
5	1.62	1.25	1.80	1.97	1.80	1.97	2.87	3.23	1.62	2.69
6	1.43	2.51	2.15	2.51	1.43	2.69	2.33	2.15	2.33	1.80
Mean	1.94	2.24	1.71	2.12	1.79	2.57	2.36	2.03	1.97	2.36
Merino. Period II.										
Clump 1	2.25	1.69	1.50	2.07	2.25	2.25	3.00	0.75	1.12	2.44
2	1.32	1.87	2.62	1.50	3.56	2.44	1.33	1.87	1.69	1.87
3	1.32	1.69	2.25	2.62	3.00	2.25	1.12	1.87	1.87	1.32
4	2.25	2.62	1.87	1.87	2.81	2.25	3.37	1.32	1.32	0.75
5	2.25	2.25	1.50	2.44	2.44	1.69	2.25	1.50	0.94	1.69
6	1.87	1.69	1.87	2.25	0.94	2.07	2.44	2.07	1.87	1.32
Mean	1.88	1.97	1.94	2.13	2.50	2.15	2.25	1.56	1.47	1.57

<u>Analysis of Variance</u>

Source of Variation	Sums of Squares corrected	D.f.	Mean Square	F.	P.
Treatment	3.20	1	3.20	3.73	N.S.
Transect	2.65	9	0.29	0.34	N.S.
Tre x Trans (E1)	7.71	9	0.86		
Clump	0.64	5	0.13	0.34	N.S.
Clu x Tre x Tra	10.69	45	0.24	0.63	N.S.
Error 2	18.81	50	0.38		
Period	15.72	1	15.72	61.65	***
Per x Tre	0.07	1	0.07	0.27	N.S.
Per x Tra	4.67	9	0.52	2.03	*
Per x Clu.	0.61	5	0.12	0.47	N.S.
Per x Tre x Tra.	3.67	9	0.41	1.61	N.S.
Error 3	24.27	95	0.26		
Total	50.01	239			

Period II (2.02) > Period I (1.43)

Table 4. Frequency of Defoliation of "Old" and "Young" Tillers (no. defoliations /15 days).

Romney. Period I.										
Transect	1	2	3	4	5	6	7	8	9	10
Old	1.86	1.68	1.86	1.89	1.75	2.03	1.89	2.24	1.75	1.75
Young	1.44	1.13	1.56	0.94	0.81	1.06	0.81	1.56	1.87	1.75
Period II.										
Old	1.91	2.18	1.60	2.30	1.72	2.30	2.30	2.18	1.99	2.42
Young	1.63	1.92	1.92	1.42	1.92	2.27	2.34	1.42	1.78	1.99
Merino. Period I.										
Old	2.00	2.24	1.51	1.12	1.72	1.30	1.37	0.98	1.58	1.16
Young	1.87	1.69	1.69	0.63	1.69	1.69	1.15	1.38	0.94	0.94
Period II.										
Old	1.97	1.97	2.10	2.27	2.35	2.27	1.76	2.30	1.34	1.68
Young	1.65	2.03	1.50	1.73	2.78	1.88	0.98	2.10	1.88	1.35

Analysis of Variance.

Source of Variation	Sums of Squares corrected	D.f.	Mean Square	F.	P.
Treatment	0.27	1	0.27	0.96	N.S.
Transect	1.09	9	0.12	0.43	N.S.
Tre x Tra (E_1)	2.55	9	0.28		
Category	1.55	1	1.55	19.38	**
Cat x Tre.	0.27	1	0.27	3.38	N.S.
Cat x Tre x Rep.(E_2)	1.40	18	0.08		
Period	3.74	1	3.74	17.8	**
Per x Cat.	0.17	1	0.17	0.81	N.S.
Per x Cat x Tre.	0.25	1	0.25	1.19	N.S.
Error 3	7.9	37	0.21		
Total	19.16	79			

"Old" (1.86) "Young" (1.58).

Period II (1.94) Period I (1.50)

Table 5. Severity of Defoliation. (mm removed per defoliation and % removed per defoliation).

Romney. Period I.	Measured difference in G.L.L.	Correction*	mm G.L.L. removed	% G.L.L. removed
July 3 - 7	5.08	1.28	6.36	20.44
7 -10	7.66	1.53	9.19	28.25
10 -13	2.17	0	2.17	7.13
13 -17	6.25	2.0	8.25	23.81
17 -20	7.50	0	7.50	28.11
20 -23	4.50	0	4.50	20.57
23 -25	5.00	0.20	5.20	24.04
Period II.				
August 1 - 3	4.35	0.40	4.75	32.36
3 - 6	0.25	1.83	2.05	22.50
6 - 8	3.62	0.20	3.82	36.28
8 -10	3.48	0.90	4.38	43.45
10 -13	2.14	0.15	2.29	25.81
13 -15	1.35	0.62	1.97	23.51
15 -18	2.01	0.63	2.64	29.63
18 -21	0.19	1.32	1.51	21.00
Merino. Period I.				
July 7 -10	4.61	0	4.61	13.56
10 -13	4.68	2.58	7.26	22.86
13 -17	5.90	3.00	8.90	28.68
17 -20	5.19	0.18	5.37	16.49
20 -23	6.83	1.00	7.83	30.69
23 -25	5.04	0	5.04	20.59
Period II.				
August 6 -10	2.12	0.36	2.48	21.55
10 -13	2.53	0.45	2.98	26.66
13 -15	3.59	0.62	4.21	39.79
15 -18	2.60	0.93	2.53	26.74
18 -21	1.82	0.90	2.72	30.94
21 -24	2.91	0.10	3.01	42.28

* Mean increase in G.L.L. of ungrazed tillers over observation interval.

Analysis of Variance (a) mm G.L.L. removed/defoliation

Source of Variation	Sums of Squares corrected	D.f.	Mean Square	F.	P.
Treatment	14	1	14	0.01	N.S.
Period	8963	1	8963	6.09	*
Tre x Per.	20	1	20	0.01	N.S.
Error	32394	22	1472		
Total	41381	25			

Period I (66.68) > Period II (29.53) (0.05).

(b) % G.L.L. removed per defoliation.

Source of Variation	Sums of Squares corrected	D.f.	Mean Square	F.	P.
Treatment	4	1	4	0.08	N.S.
Period	297	1	297	6.31	*
Tre x Per.	29	1	29	0.62	N.S.
Error	1036	22	47.09		
Total	1366	25			

Period II (30.89) > Period I (23.42) (0.05)