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**A COMPARATIVE STUDY OF DEFOLIATION IN  
*HOLCUS LANATUS* AND *LOLIUM PERENNE*  
PASTURES GRAZED BY SHEEP**

**A thesis presented  
in partial fulfilment of the requirements  
for the degree of Master in Agriculture  
at Massey University**

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**1993**

## ABSTRACT

Objectives of this study were (i) to extend limited information on the assessment of relative defoliation of grass and legume components in mixed ryegrass/white clover and yorkshire fog/white clover pastures, (ii) to test whether the balance of preference between ryegrass and clover differed from that between yorkshire fog and clover, and (iii) to compare the behaviour and the potential reaction of the two grass species under grazing conditions.

Observations were made on plots of ryegrass/white clover and yorkshire fog/white clover grazed by sheep at high (12% live weight) and medium (6% live weight) herbage allowance. There were four replicates of each treatment, which were grazed in rotation over a four week period. Detailed sward measurements were made before and after grazing. Measurement of herbage mass, sward height, sward components, pasture structure and defoliation are reported.

Sward surface heights were very similar for the two swards both before and after grazing. The sown grasses formed the dominant proportions in both swards, while white clover proportions were similar. The proportion of dead material was higher for yorkshire fog/white clover pasture than ryegrass/white clover pasture both before and after grazing.

Tiller populations were higher for yorkshire fog than ryegrass (10355 vs. 6505  $\pm$ 919 m<sup>2</sup>). Mean stem length was greater for yorkshire fog than ryegrass (62.3 vs. 35.0  $\pm$ 2.8 mm), and the distribution of stem length showed a stronger positive skew. Yorkshire fog had a shorter leaf length than ryegrass. The population density of white clover nodes was similar in the two swards. White clover nodes in the two swards were quite similar in leaf weight, number and area both before and after grazing.

The defoliated heights for clover in ryegrass/white clover and yorkshire fog/white clover swards (3 cm and 5 cm respectively) were similar at both low and high grazing allowance. The proportion of grass in the grazed stratum was higher for ryegrass than for yorkshire fog pasture before grazing, but the proportion of white clover was lower.

Three parameters estimated from pre- and post-grazing measurements on individual grass tillers and clover nodes were used in the interpretation of pasture defoliation: namely defoliation frequency, defoliation severity and defoliation pressure (frequency  $\times$  severity). In ryegrass/white clover pastures, the defoliation of leaf was significantly higher for ryegrass than white clover for all three parameters. In the comparison within yorkshire fog/white clover pastures, the defoliation frequency was not different between grass and clover, but the severity of defoliation and defoliation pressure were significantly higher for grass than clover. Ryegrass stem was grazed more severely than white clover petiole in ryegrass/white clover pastures. Defoliation parameters for yorkshire fog stems and white clover petioles in yorkshire fog/white clover pastures showed smaller and not significant differences. There was a highly significant effect

of allowance on leaf defoliation in ryegrass/white clover pastures, but the effect was less marked in yorkshire fog/white clover pastures.

More ryegrass leaf was grazed per day than yorkshire fog leaf. The proportion of leaf removed and the pressure of defoliation were higher in ryegrass than in fog. When white clovers were compared between the two swards, there were no differences in any of the three defoliation parameters. Leaf defoliation effects were greater at medium allowance than at high allowance. For all parameters, allowance effects were greater for grass than clover.

The fact that grasses were defoliated more severely than the companion clovers in both swards reflected the effects of vertical distribution of sward components. However, the much lower defoliated height for clovers in both swards strongly suggested that sheep actively selected clover in the mixed swards despite the fact that clover was distributed much lower in the sward canopies. The greater defoliation of ryegrass than yorkshire fog leaf was attributed to greater preference of the animal for ryegrass than yorkshire fog in comparison with the companion clover.

## ACKNOWLEDGEMENTS

My chief supervisor professor J. Hodgson and my co-supervisor Dr.I. Valentine are gratefully acknowledged for their very warm encouragement, patient supervision and kind assistance in various ways throughout this project.

Thanks are due to my fellow researcher Mr. F. Montossi who co-laboured with me throughout the field and laboratory measurements for his very warm assistance and advice.

Many colleagues in The Plant Science Department were generous in giving time for discussion or help in various ways, these helpers are: Mr. M. Osborne (techniques for trial lay out), Mr. T. Lynch and Mr. D. Sollitt (applying equipment), Ms. J. Harrigan (field and lab assistance); Dr. I. Gordon, Mr. B. Butler, Mr. S.C.D. Silva, Mr. H.M. Nodoushan, Mr. M.R. Ghannadha Mr. M.U.H. Awan (Data analysis) and others.

Finally, My wife Yaoping Zhang is thanked for her considerable encouragement, especially in supporting me to spent a long time overseas to complete the project.

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## CHAPTER 1. INTRODUCTION

Perennial ryegrass (*Lolium perenne*) is a dominant grass species in New Zealand pastures. However, much effort has been made during the past decade to find viable alternatives to ryegrass pastures which could have a greater pasture/animal production in seasons and environments where ryegrass productivity is limited. Yorkshire fog (*Holcus lanatus*) is one of such alternative candidates.

During recent years, the importance of yorkshire fog in association with other species, especially in wet or peaty areas and in hill pastures, has been recognized. In some of the high-producing pastures in New Zealand, yorkshire fog persists as a minor component. Researches have shown that there is clearly a need for more information about the value of yorkshire fog for animal performance, and animal reaction/preference when grazing on yorkshire fog. This could lead to a better understanding of grazing management in mixed pastures containing this species.

In the autumn of 1992, an experiment was set up to provide a comparison of sheep grazing grass/clover swards based on either yorkshire fog (cv 'Massey Basyn') or perennial ryegrass (cv 'Grasslands Nui'), each grown with white clover (cv 'Grasslands Tahora') at two grazing pressures.

The experiment was designed to compare and contrast the reactions of grazing animals to yorkshire fog/white clover and perennial ryegrass/white clover pastures especially in winter, to extend the limited information in the assessment of relative frequency and severity of defoliation of grass and legume components in each treatment, and to test whether the balance of preference between yorkshire fog and clover differed from that between ryegrass and clover.

## CHAPTER 2. LITERATURE REVIEW

### 2.1 Introduction

In this section, a brief outline of research on pasture ecology and grazing management is given, with particular reference to research on sward characteristics and pasture defoliation; the procedures for investigating selective grazing activity are reviewed briefly.

The research has given valuable insights into ways of improving animal productivity through management practices and through identifying plant characteristics that could be changed to improve their nutritional value (Black, 1984). The manipulation of pasture species to offer a species composition and sward structure appropriate for grazing animals is important. The replacement of grass with legumes or the provision of a more leafy pasture offer alternative strategies.

### 2.2 Selected species

This section provides a brief review of the agronomic characteristics of the two grass species used in the grazing trial, perennial ryegrass (*Lolium perenne*, L.) and

Yorkshire fog (*Holcus lanatus*, L.).

Perennial ryegrass is a long-lived grass which is capable of producing many tillers. The plant is nutritious and palatable, and stands up to hard grazing. However, the performance of this grass is limited under poor conditions, such as low fertility or rainfall. The required annual rainfall is between 850 mm and 1030 mm. A mild climate is important during the growth season. It grows well when mixed with white clover and is distributed extensively throughout New Zealand (Korte, et al, 1987). The reaction of perennial ryegrass to defoliation was summarised by Bircham and Hodgson (1983) who showed that a homeostatic mechanism exists in continuously grazed swards, whereby compensatory changes in population density and tissue turnover on individual plant units combine to maintain relatively constant net production of green herbage over a range of herbage mass and LAI (Leaf Area Index).

A great deal of research has been conducted on perennial ryegrass, and as a result it provides the standard with which to assess the performance of new introductions.

Yorkshire fog is a loosely to compactly tufted, soft, hairy perennial plant, growing 20-100 cm high. In all cases hairiness is a prominent feature. It is commonly found in many of the temperate pastoral grasslands of the world (Bocher and Larsen, 1958) and is widely distributed throughout New Zealand (Jacques and Munro, 1963). Ecologically Yorkshire fog is exceptional for its almost complete lack of edaphic

specialisation (Beddows, 1961 a; Levy, 1970). It may be found growing on soils of low to high fertility and tolerates not only highly acidic soils but water-logged and wet soils as well as soils of average moisture content. In addition, yorkshire fog has a wide tolerance of temperature regimes (Mitchell and Lucanus, 1960). It was concluded that ryegrass is a superior grass to yorkshire fog on upland soil with high nitrogen status, moderate phosphate status and a high pH (Morton et al, 1992).

Yorkshire fog is present as an indigenous species in upland pastures (Swift et al., 1983). It has also shown high persistence and yield when introduced into *Molinia* and *Nardus* pastures (Hughes and Nicholson, 1961). Indigenous yorkshire fog from both Great Britain and Germany has given higher production than ryegrass at low nitrogen levels (Haggar, 1976; Frame, 1982; Watt, 1987) under cutting at lowland sites.

Although suited to a lenient system of defoliation, yorkshire fog also competes under close grazing (Watkin and Robinson, 1974). The seasonal production was shown to compare favourably with the commonly used ryegrass in New Zealand. There are however undesirable features including the presence of dead basal material and relatively low acceptability of yorkshire fog at certain stages of growth. Jacques (1974) has suggested that improvement of the relative acceptability of yorkshire fog by selection and breeding within the strain might be possible.

The *H. lanatus* cultivar Massey Basyn is the result of a long-term selection and breeding programme carried out at Massey University, New Zealand (Jacques et al,

1962). The trials (Watkin and Robinson, 1974) in New Zealand have shown that Massey Basyn gave similar dry matter production to ryegrass and promoted similar live weight gain in sheep.

Many workers have commented upon the hairiness of the leaves and sheaths causing an unpleasant touch sensation to the animal's mouth (Garner, 1963). Pubescence is one factor commonly listed as being particularly responsible for the rejection of yorkshire fog (Davies, 1925; Stapledon, 1927; Cowlshaw and Alder, 1960; Jacques and Munro, 1963, Watt, 1978). However, Cameron (1979) stated that leaf pubescence appeared to be unimportant in determining sheep preference, negating previously held views to the contrary. He also reported that among the characters of yorkshire fog, the presence of inflorescence, dead leaf and sheath material and crown rust infection appeared to be the most important plant characters determining the acceptability of yorkshire fog over the summer to early-winter. Sheep rejected clumps containing a high proportion of inflorescence, dead leaf and sheath material and crown rust infection.

The accumulation of dead material in leniently grazed yorkshire fog pastures is a serious problem (Jacques et al, 1974). Cowlshan and Alder (1960) found an relationship between percentage dead leaf and sheath of yorkshire fog and preference ranking to bullocks. However where it is not allowed to become rank, sheep will consume yorkshire fog readily throughout most of the year (Watkin, 1960). Accumulation of dead basal material provides a medium for the growth of

*Pithomyces chartarum*, the fungus causing facial eczema in grazing animals, encouraged by the lenient grazing of yorkshire fog (Hartley, 1973).

Studies have shown that perennial ryegrass and yorkshire fog offer a nice contrast in tiller population, tiller size and growth habit (Butler,1986). They are similar in temperature and moisture requirements and the acceptability to livestock. However, yorkshire fog has a lower suitability for intensive irrigated pastures, lower fertility requirement and a higher tolerate for wet, acid and infertile soils compared to ryegrass. Detailed information on the two species in terms of the relative response and tolerance to grazing management and other factors was given by Scott et al (1985).

### **2.3. Tiller research overview**

Tiller dynamics has been studied by a number of authors. Plant morphology, tiller production, tiller longevity and seasonal patterns of tiller natality and mortality, the effect of environment and grazing management are the major aspects of those studies.

The studies of tiller longevity and seasonal patterns of tiller natality and mortality has been conducted at four levels of complexity (Matthew,1992). First, the changes in tiller population over a period of time, and the increase in tiller population density in later winter or early spring are featured by many authors including Garwood

(1969) and Hunt (1989). Tiller appearance and death rates obtained by short term monitoring of tagged tillers (Garwood, 1969; L'Huillier, 1987 and Hunt, 1989) represent a second level of complexity. Thirdly, a very few studies have involved the observation of individual tillers for 1 to 2 years in order to establish the longevity of tillers appearing at particular times of the year (Matthew, 1992). Such data can be presented as a tiller age-cohort survivorship diagram (Jewiss, 1966). The data of Garwood (1969) and Korte (1986) illustrate well the way in which this type of information can be used to identify differences in the behaviour of different swards. A similar seasonality of tiller natality and mortality was also recorded by L'Huillier (1987). The data of Matthew (1992) confirms that replacement of the over wintering tiller population at flowering is a feature of tiller population dynamics. The question of which age-classes of parent tillers had produced the replacement daughter tillers represents a fourth level of complexity in defining tiller population dynamics.

It is concluded that the grass plant is a dynamic population of short-lived tillers of different origins and ages (Colvill, 1984; Langer, 1956). The survival of an individual plant depends on the balance between the production of new tillers and the death of established tillers, and there are marked seasonal flushes in tiller production and death influenced by many factors. Studies in swards with a number of grass species have revealed a similar dynamic pattern of tillering, and together with agronomic studies have emphasised the degree and rapidity of turnover of tillers in the sward (Colvill, 1984). The reproductive phase of plant development, defoliation effects and physiological factors are evidently important in regulating the pattern of tiller birth

and death. Rates of appearance, growth and death of tillers determine production and persistence of grass in swards, and the contribution to botanical composition in mixed swards. Various sources have shown that knowledge of tiller population dynamics assists interpretation of agronomic information.

#### **2.4. Sward characteristics and herbage composition**

Information on pasture condition such as herbage mass and sward height (Freer, 1981) is important to the development of ways in which pasture limitations may be overcome and the potential of herbage intake and animal production may be approached.

The major variables governing intake rate are the structure of the vegetation such as height, density and the vertical distribution of biomass (Black & Kenny, 1984; Hodgson, 1985; Burlison et al, 1991). Pasture height and/or pasture density influence the ease with which the animal can prehend the pasture and hence the rate of pasture intake and daily intake. At present pasture height appears to be the best predictor of bite size and intake. From low to moderate bulk density swards, height almost entirely determined bite depth and largely determined bite volume and bite weight (Laca et al, 1992). In the studies of Burlison et al (1991) the effect of surface height and grazed stratum bulk density were independent and additive, resulting in a planar response surface.

Previous ingestive behaviour research have provided the conceptual basis for understanding the causative relations between the structural characteristics of swards and the herbage intake of grazing animals, which has influenced priorities in plant selection and in the management of swards and grazing animals. Pasture structure, pasture mass/height and pasture allowance are probably the most important factors limiting intake by grazing ruminants in temperate pastures. This concept is used in pasture management and more importantly in manipulating growth of animals.

## **2.5. Grazing management**

### **2.5.1. Grazing impact on tiller dynamics**

Swards may respond to defoliation by net gains, net losses or no overall changes in tiller populations, depending on initial numbers at the time of defoliation, severity of defoliation and the time of year. During the spring the tendency will be net gains, but during the autumn the opposite will be the case. In late summer a sward defoliated intermittently may develop a stand of tillers sufficiently dense to permit rapid canopy development and supply further tillering (Davies,1977).

Frequencies and intensities of grazing were researched by Brougham (1957). The significant feature of his experiment in relation to pasture management is that higher yields of herbage can be obtained from frequent grazing. At the commencement of the experiment, numbers of tillers was relatively uniform. However, marked

differences developed under the various grazing systems. Hard grazing following long spelling increased the loss of tiller growing points and caused death. Tiller appearance rates were higher under hard grazing management than under lax grazing. Where tiller density is higher, it follows that either tillers must be longer lived, or appearance rates higher for such a difference to be maintained.

Arosteguy (1982) noted that compared to intermediate levels of defoliation, more severe or laxer levels of defoliation have been observed to result in lower tiller population density. Also, continuously grazed swards had higher tiller populations than similar rotationally grazed swards (Hodgson & Wade, 1978; Tallowin, 1981). Parsons et al (1983) showed that swards maintained by continuous hard grazing had higher tiller numbers than leniently-grazed swards. The mean weight of whole tillers and the loss of matter in the death of whole tillers were greater under lenient grazing than under hard grazing.

Tiller removal (loss) is higher under rotational than continuous grazing (Hunt, 1989), higher under cattle grazing than sheep grazing (Arosteguy, 1982) and higher under more severe grazing (Bircham & Hodgson, 1983). Tiller populations in cattle-grazed swards at equivalent sward height and herbage mass appear to be lower than in swards grazed by sheep (Arosteguy et al, 1983).

It is true that where a closely grazed sward with a high tiller population density is allowed an extended period of regrowth, gross leaf accumulation is higher than on

a similar sward with a different grazing history and a lower tiller population density (Bircham, 1981; Parsons et al, 1984; Grant et al, 1988). Therefore, manipulation of tiller density can increase herbage production. The detailed information on sward behaviour can be used to generate pasture production advantages. Grazing effects on reproductive tiller density have been reported by Butler (1986) who considered that reproductive tiller appearance was reduced if swards were grazed to a low residual from late September, and increased under more frequent grazing. Matthew's (1992) trial suggested that the cycle of early summer tiller formation from winter-formed nodes after flowering might be influenced by grazing management.

### **2.5.2. Grazing impact on plant communities**

The repeated disturbance of grazing can modify species behaviour patterns so as to generate niche differentiation without suppressing competitive interactions (Fitter 1986). Grazing may play a fundamental role in shaping and maintaining the structure of plant communities. Grazing may reduce numbers of plants through mechanisms which are either dependent on or independent of population density.

Herbivory affects plants not only in the vegetative and reproductive phases but also in the pre-dispersal and post-dispersal phases of seeding activity. Furthermore, because herbivory often does not result in mortality but in reduced growth and seed production, its effects may be manifested only as reductions in the size of later generations (Verkaar 1987). It is quite evident that the risk of death increases and that

life expectancy decreases with the increase in intensity of defoliation. Under conditions of high density, defoliation increasingly reduces plant survival. However, grazing is the ecological factor that destroys competitive monopoly. Without defoliation, most organisms are limited by interspecific competition for resources. Grazing reduces competition among the producers and allows the existence of many more type of plants.

## **2.6. Food intake and selective grazing**

Selective grazing is defined as the difference between diet and sward composition or some ratio of the two (Hodgson, 1985). At least three factors influence diet selection, namely, (1) ease of eating, measured as potential intake rate when a forage is offered alone to trained animals for short periods, (2) sensory factors relating to taste, odour and tactile stimulation, (3) the quantity and spatial distribution of components within a sward.

It is generally accepted that animals prefer legume to grass, leaf to stem and living material to dead. In general terms the degree of selection exerted by grazing animals between alternative sward components (plant species or morphological units) increases as within-sward contrasts in plant maturity or physical and biochemical characteristics increase. However, preferences are unlikely to be influenced directly by conventional nutrient components in most circumstances (Hodgson, 1985).

There is a widely-held belief that the diet of sheep grazing a mixed sward of grass and clover contains a higher proportion of clover than is found in the sward, although Thomson (1978) has pointed out that there is little experimental evidence to confirm this and Arnold et al (1966) and Hodge & Doyle (1967) observed only small differences between the proportions of clover in the diet and in the sward and could find no clear relationship between the two.

Patch selection is influenced by sward height and by clover content, and their effects are additive. Tall patches are preferred, and intermediate contents of clover are selected in preference to low or high contents (Illius et al,1992). Such a pattern of selection would tend to reinforce the patchy distribution of the grass and clover components of mixed swards. The same author also described the curvilinear pattern of preference with increasing sward clover content and suggested the existence of counteracting or non-monotonic influences on preference.

The animal has to select and harvest its diet from a mixed population of forage plants which vary, within and between individuals. However, such selection depends on the amount of herbage available and its distribution within the sward. For example, the distribution or accessibility of white clover relative to grass leaf may be a major determinant of selection. If the most acceptable components are distributed too thinly on the ground for the animal's appetite to be readily satisfied in a grazing day, a balance is struck between a lowered level of preference and a depression in intake (Clark and Harris, 1985).

Hunt and Hay (1989) reported the results of studies on the preferences of deer offered access to a range of plants in single species plots. The preferences was observed for legumes over grasses where deer were offered single plant species in free choice trials. Bootsma et al (1990) reported the results of a preliminary investigation of diet selection by weaned stags grazing mixed ryegrass/legume pastures.

Milne et al (1982) showed that the apparent preference for clover exhibited by sheep grazing mixed *L. perenne* and *T. repens* pastures was explained by a higher proportion of clover foliage in the upper strata than in the sward as a whole. Bircham and Hodgson (1983) observed a concentration of *T. repens* leaf in the upper horizons of ryegrass/clover pastures grazed by sheep under continuous stocking management, which was related to greater proportionate defoliation of *T. repens* than *L. perenne*, and L'Huillier et al (1984) also showed that the distribution of green leaf within the sward canopy influenced selective grazing by sheep. However, diet selection from mixed swards is not always determined by the distribution of grass and clover foliage within them (Clark et al, 1986). Clark et al (1984) and Curll & Wilkins (1982) observed similar frequencies of defoliation for marked units of *L. perenne* and *T. repens* in pastures grazed by sheep, but pasture structure was not defined in these studies.

Sheep frequently penetrate to about half the depth of the leafy zone of grass swards (Burlison, 1987). This may indicate that animals adjust their bite depth in relation to the depth of the leafy, pseudo-stem free zone of the sward, as suggested by Barthram

(1984). Further, Milne et al (1982) found that the bite depth/ height ratio of sheep on ryegrass white clover swards increased with height; possibly reflecting either selection by the sheep for white clover, or the proportionally deeper stem-free leafy zone with increasing height.

It is often said (Watkin and Clements, 1978) that selection of white clover rather than grass can lead to overgrazing. However, Clark et al (1982) found only small differences between the proportions of white clover in the sward and in the diet of sheep on North Island hill country pastures. Arnold et al (1966) and Grimes et al (1966) reported similar findings in different pasture communities in Australia. On the other hand, Bootsma et al (1990) reported that the proportion of clover in ingesta samples from deer was consistently smaller than in the pasture, whereas plant observations showed similar frequency and severity of defoliation for grass and clover.

Milne et al (1982) reported clover selection in a vertical plane from the grazed strata of swards and suggested that taller, less dense swards allow more selection. Clark and Harris (1985) reported the results of clover selection in a horizontal plane which showed that more clover was taken from strip swards than from mixed swards especially at the low clover levels.

Curll (1982) found that there was little evidence of selective defoliation of the grass and clover components of mixed swards at low herbage mass (0.5 t DM/ha). Above

1 t DM/ha a curvilinear relationship (Arnold et al, 1966; Grimes et al, 1966) existed between swards and dietary clover proportions, with 4 times as much clover in the diet as in the sward at 5% but little selection at 40%. This relationship between pasture mass and selective grazing needs to be evaluated by food intake analysis.

In summary, the most important factors likely to influence the proportion of clover in the diet are (i) the proportion of clover in the sward, (ii) the relative distribution of the plant parts of clover and grass within the sward canopy, and (iii) the herbage mass and the height and density characteristics of the sward (Milne et al, 1982).

## **2.7. Procedure for evaluating selectivity**

Sward structure can have a major influence on pasture consumption (Hodgson, 1985; Forbes, 1988). In order to isolate the components of sward structure that determine defoliation rate and preference, Black and Kenney (1984) constructed a series of artificial pastures in which height and density were varied independently by placing tillers from vegetative ryegrass in holes at different spacings in pressed hardwood sheets. The rate of intake by sheep grazing these pasture increased with both the height and density of pasture and was best described by herbage mass per unit area effectively covered by one bite. Subsequent studies (Kenney and Black, 1986) showed that both intake rate and the pasture availability at maximum intake rate depended greatly on the distribution of plant material within the pasture horizons.

The chemical composition of pasture plant material varies widely between species and their component parts such as leaf, stem, flower and seed. The composition of each component within a species can change markedly as the plant matures, and composition also varies with growing conditions. Thus, within any pasture, there is normally a large range in the chemical composition of individual plant components available to grazing animal for selection (Black, 1984). Therefore, sward or diet composition provides a basis of evaluating selectivity.

Meijs et al (1982) stated that it is often necessary in grazing trials to obtain information on the nutritive quality and botanical composition of herbage ingested by the grazing animal. Due to selection by the animal this will often differ from that of the herbage on offer and some attempt to assess dietary composition other than that based on herbage on offer is essential if relative differences between pastures in terms of animal production are to be interpreted critically. The assessment techniques of quality and botanical composition of grazed herbage were described in detail by the same authors.

Hodgson (1981) summarized that there are three techniques for evaluating selectivity: (i) Changes in sward composition: herbage mass, sward height, canopy structure, and the botanical, morphological or chemical composition are measured and used to explain the observed effects of experimental treatments on herbage production or on the performance of grazing animals, and as a guide to sward management. This kind of measurement provides an instantaneous assessment of conditions in the sward at

a point in time. Since these conditions change continuously it is usual to make such measurements at intervals in order to provide information on patterns of change over individual periods of defoliation and regrowth. (ii) Differences between sward and diet composition: under grazing conditions the amount of herbage harvested from a sward must be estimated from measurements of sward changes during grazing or indirectly from observations on animals. Measurements may be made in terms of the total herbage, or of the contribution of particular species or plant parts. Measurements of this kind normally provide an assessment of the net accumulation of the herbage over time, representing the balance between the growth of new tissue on the one hand and losses (removed by grazing animals) on the other. (iii) Differential defoliation of components are often estimated by observations on the life histories of individual plants or plant components that may be complemented by information on the spatial and temporal patterns of individual shoots and leaves.

Information on the selective removal of plant morphological or botanical components of a sward on the part of the grazing animal needs to be tempered by considerations of the distribution of the alternative components within the sward canopy (Hodgson, 1985). Thus the differences of sward components before and after grazing could reflect the reality of selective defoliation.

Diet selection was estimated by Bootsma et al (1990) both from samples of fresh ingesta collected from rumen fistulated animals and defoliation of marked populations of grass tillers and clover nodes. In this study the frequency and severity of

defoliation of marked units were recorded as the basis for assessment.

In the present study, measurements of herbage mass, sward height, sward components and tiller and node populations were conducted to evaluate the state of the swards. Measurements of sward structure and marked tillers and nodes were used to estimate selective defoliation.

## CHAPTER 3. MATERIALS AND METHODS

### 3.1. Site

The experiment was conducted at the Pasture and Crop Research Unit Massey University, New Zealand during May to June 1992 (late Autumn and early Winter). The soil at the site is a Tokomaru silt loam (Typic Fragiaqualf). Long term average monthly temperatures for the site range from 8.0 °C (July) to 17.6 °C (January). The pastures had been sown in March 1988 after approximately 2 years in crops and the seed mixtures used were perennial ryegrass (*Lolium perenne* L. cv. 'Grasslands Nui') 18 kg ha<sup>-1</sup> or yorkshire fog (*Holcus lanatus* L. cv. 'Massey Basyn') 3 kg ha<sup>-1</sup>, each with 2 kg ha<sup>-1</sup> white clover (*Trifolium repens* L. cv. 'Grasslands Tahora'). Mean annual rainfall is 995 mm. Plots of both pastures had been managed under continuous stocking for two years. One month prior to the experiment nitrogen fertilizer was applied, plots were grazed, and then left to accumulate herbage.

### 3.2. Experimental design

A split plot design was used in the project. The trial was established on four paddocks of 0.2 ha for each species, and each paddock was split in the ratio 2:1 to

provide two grazing allowances, namely high and medium allowance. Paddocks were distributed at random within the experimental area, and were prepared to provide four replications of each grass species which were grazed in sequence, grazing of each replicate occupying a period of 3-4 days. The design of the experiment is show in Table 1.1.

**Table 3.1. The design of the experiment**

Treatments	Levels
Two sward species	Yorkshire fog/white clover
	Perennial ryegrass/white clover
Two allowances	High allowance (12% live weight per day)
	Medium allowance (6% live weight per day)

There were 6 sheep in each plot (Table 1.2) All sheep were randomized prior to the beginning of the trial according to live weight.

### **3.3. Measurements**

#### **3.3.1. Herbage mass and sward height**

Herbage mass was estimated by using quadrat cutting before and after grazing. Six

**Table 3.2. Experimental plots layout (with four such replications)**

Species	Allowance	
	Medium	High
Ryegrass/white clover	RM	RH
Yorkshire fog/white clover	FM	FH

0.1 m<sup>2</sup> quadrats in each plot were cut to ground level using an electric shearing handpiece. The samples were washed and then dried in a forced-draught oven for 72 hours at a temperature of 70-80 °C , and weighed using a electric scale. Sub-samples were drawn from the bulked samples cut to ground level in each plot to measure botanical components. Each of the sub-samples was dissected into categories of species and morphology (leaves, stems, live and dead tissues). The components were dried and weighed as above.

Sward height was measured before and after grazing, using the Hill Farming Research Organisation (HFRO) sward stick (Bircham, 1981; Barthram, 1986). Five readings were made inside each quadrat when herbage mass samples were collected, giving 30 readings for each plot. Within each plot 40 extra readings were then made randomly.

### **3.3.2. Pasture structure**

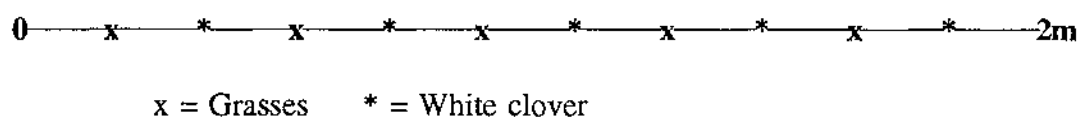
The vertical distribution of plant tissue within the sward canopy was measured using an inclined point quadrat (Warren Wilson, 1963 a) set at  $32.5^{\circ}$  to the horizontal and 100 contacts were recorded in each plot before and after grazing respectively.

Contacts were recorded for species, morphology (leaf, stem, petiole) and state (live, dead).

### 3.3.3. Marking tillers and nodes

Tiller and node tagging was conducted to evaluate the selected defoliation of individual species. Five transects of 2 m length were set in each plot with tillers and nodes tagged at twenty centimetre intervals alternately (Figure 3.1). This gave a total number of 25 tagged tillers and 25 nodes in each plot. Each tagged tiller and node was recorded prior to grazing and after grazing to determine the numbers defoliated and the amount of plant tissue removed from each. Grass leaf, pseudo-stem and clover petiole were measured in length, but the leaf area was estimated for clover leaf using the method of Williams et al (1964).

The state of morphology were recorded as live tissue and dead material.



**Figure 3.1. The transect layout for marking tillers and nodes**

Estimates of the amount of leaf and stem tissue removed from each marked unit (lamina and pseudo-stem length for grasses; lamina area and petiole length for clover) were then analyzed using a simple tissue defoliation package (Butler, 1991).

#### **3.3.4. Tiller cores**

20 tiller cores (diameter = 53 mm) were collected in each plot before grazing. The cores were hand separated into categories of species (ryegrass, yorkshire fog, white clover, other grasses, weeds), and the number of units (tillers or nodes) of each group of species were calculated.

#### **3.3.5. Tiller and node dissection**

10 tillers and 10 nodes were sub-sampled from the mixture of 6 cut quadrats in each plot (see also Section 3.3.1). These tillers and nodes were hand separated into pseudo-stem, grass leaf, petiole and clover leaf. The materials of each category were measured (length for grass leaf and area for clover leaf), dried for 48 hours and then weighed.

### **3.4. Statistical analysis**

All statistical analysis were carried out using the statistical package SAS (SAS Institute Inc., 1985).

Pasture mass, sward height and botanical composition were analyzed as a split plot design (species split into low and high grazing allowances) before and after grazing separately, based on plot mean values. Tiller size and tiller or node population data were analyzed using the same design.

A point quadrat package (Butler, 1991) was used in the analysis of inclined point quadrat data. The variances of means were calculated using Student's t test (Steel and Torrie, 1981).

Estimates of the defoliation of individual tillers (Grant, 1981) were derived from the tissue turnover package (Butler, 1991). Analysis of variance of the data were first based on transect means within plots for the constituent grass and clover components. Plot means for these components were then used in analysis of variance (a) within ryegrass/white clover and yorkshire fog/white clover treatments respectively, and (b) over all treatments, in each case with four replicates.

## CHAPTER 4: RESULTS

### 4.1. Introduction

This chapter reports the estimates of herbage mass and sward height, botanical composition, tiller/node size and population, sward component and structure, and the measurements of pasture defoliation.

### 4.2. Herbage mass and sward height

#### 4.2.1. Herbage mass

The results in Table 4.1 indicate that there was no significant difference in herbage mass between ryegrass/white clover and yorkshire fog/white clover pastures before grazing, but after grazing the pasture mass was significantly higher for yorkshire fog ( $p < 0.01$ ). There was also no difference between grazing allowances before grazing, but significant differences existed after grazing ( $p < 0.05$ ). There were no significant interactions between the effects of sown pasture species and grazing allowances in the analysis of pasture mass.

The amount of herbage mass removed in ryegrass/white clover pasture was 1150 kg

DM/ha<sup>-1</sup> for medium allowance and 620 kg DM/ha<sup>-1</sup> for high allowance, whereas in yorkshire fog/white clover pasture the corresponding values were 980 kg DM/ha<sup>-1</sup> and 590 kg DM/ha<sup>-1</sup> respectively. Comparing the two pastures, 35% and 20% of the pre-grazing herbage mass of yorkshire fog/white clover sward were removed at medium and high allowances during grazing, compared with 55% and 26% from that ryegrass/white clover pastures.

#### 4.2.2. Sward height

The sward height data both inside and outside quadrats are shown in Table 4.2. Sward heights were similar for ryegrass/white clover and yorkshire fog/white clover pastures both before and after grazing.

Sward height inside quadrats was higher for high than medium allowance before grazing ( $p < 0.05$ ), and both pasture heights were greater for high allowance than medium allowance after grazing ( $p < 0.01$  and  $p < 0.05$ ). There was no significant interaction of species x allowance in sward height either before or after grazing.

**Table 4.1. The effect of sward and allowance on herbage mass before and after grazing (kg DM/ha)**

Grazing	Ryegrass/white clover pastures		Yorkshire fog/white clover pastures		SEM	Significance of effects		
	Medium allowance	High allowance	Medium allowance	High allowance		Species	Allow- ance	Inter- action
Before	2093	2398	2793	2974	169.9	NS	NS	NS
After	945	1778	1813	2385	105.4	**	*	NS
% Mass defoliated	55	26	35	20	--	--	--	--

Note: In this and following tables:

\* P<0.05    \*\* P<0.01    \*\*\* P<0.001    NS=Not Significantly different

Table 4.2. The effect of sward and allowance on sward height before and after grazing (cm)

Grazing	Measurements	Sward height (cm)				SEM	Significance of effects		
		Ryegrass/white clover pastures		Yorkshire fog/white pastures			Species	Allowance	Interactions
		Medium allowance	High allowance	Medium allowance	High allowance				
Before	Inside quadrat	13	14	12	14	0.6	NS	*	NS
	Outside quadrat	13	14	13	15	0.7	NS	NS	NS
After	Inside quadrat	6	9	7	8	0.5	NS	**	NS
	Outside quadrat	6	9	7	10	0.5	NS	*	NS

### 4.2.3. Sward components

Sown grasses formed the major component of both ryegrass/white clover and yorkshire fog/white clover pastures (Table 4.3) before and after grazing. No yorkshire fog appeared in the samples of ryegrass/white clover pastures, but ryegrass made up a substantial component of the yorkshire fog/white clover sward. The proportion by dry weight of white clover in the two swards was identical before grazing, but was slightly though not significantly higher in ryegrass/white clover swards than in yorkshire fog/white clover swards after grazing. Other grasses composed 15-25 % of herbage mass in both swards, similar to the result from point quadrat data (Section 4.4.3). Differences between treatments were not significant. Weeds were a minor proportion in the pastures. There was a tendency for a higher proportion of dead material in yorkshire fog/white clover pastures than in ryegrass/white clover, which was significant in the comparison after grazing. The proportion of dead material increased in both pastures during grazing.

Comparing pasture allowances, white clover components were significantly higher at high allowance than at medium allowance after grazing, while there was no significant difference before grazing. There were no significant differences for other components in the comparison of allowances before and after grazing.

All of the interactions between species and allowances were not significant.

**Table 4.3. The proportion of components of ryegrass/white clover and yorkshire fog/white clover pastures estimated from hand separations (proportions of DM)**

	Before Grazing						After Grazing					
	Species			Allowance			Species			Allowance		
	Ryegrass /clover	Fog /clover	SEM	Med- ium	High	SEM	Ryegrass /clover	Fog /clover	SEM	Med- ium	High	SEM
Ryegrass %	59	19	6.2 **	44	34	3.1 NS	54	12	3.6 **	31	35	2.4 NS
Yorkshire fog %	0	45	2.2 ***	21	24	2.5 NS	0	54	2.5 ***	28	27	4.3 NS
Clover %	5	5	1.0 NS	6	5	0.7 NS	8	5	1.3 NS	5	7	0.6 *
Other grasses %	24	14	3.1 NS	18	20	1.8 NS	24	10	3.7 NS	19	16	1.6 NS
Weeds %	1	4	2.4 NS	1	4	2.0 NS	1	0	0.1 **	1	1	0.6 NS
Dead matter %	9	14	2.0 NS	10	13	1.1 NS	13	19	1.0 *	16	15	2.2 NS

Ryegrass % : DM proportion of living ryegrass

Fog % : DM proportion of living yorkshire fog

Clover % : DM proportion of living white clover

Other grasses % : DM proportion of other grasses

Weeds % : DM proportion of living weeds

Dead matter % : DM proportion of total dead material

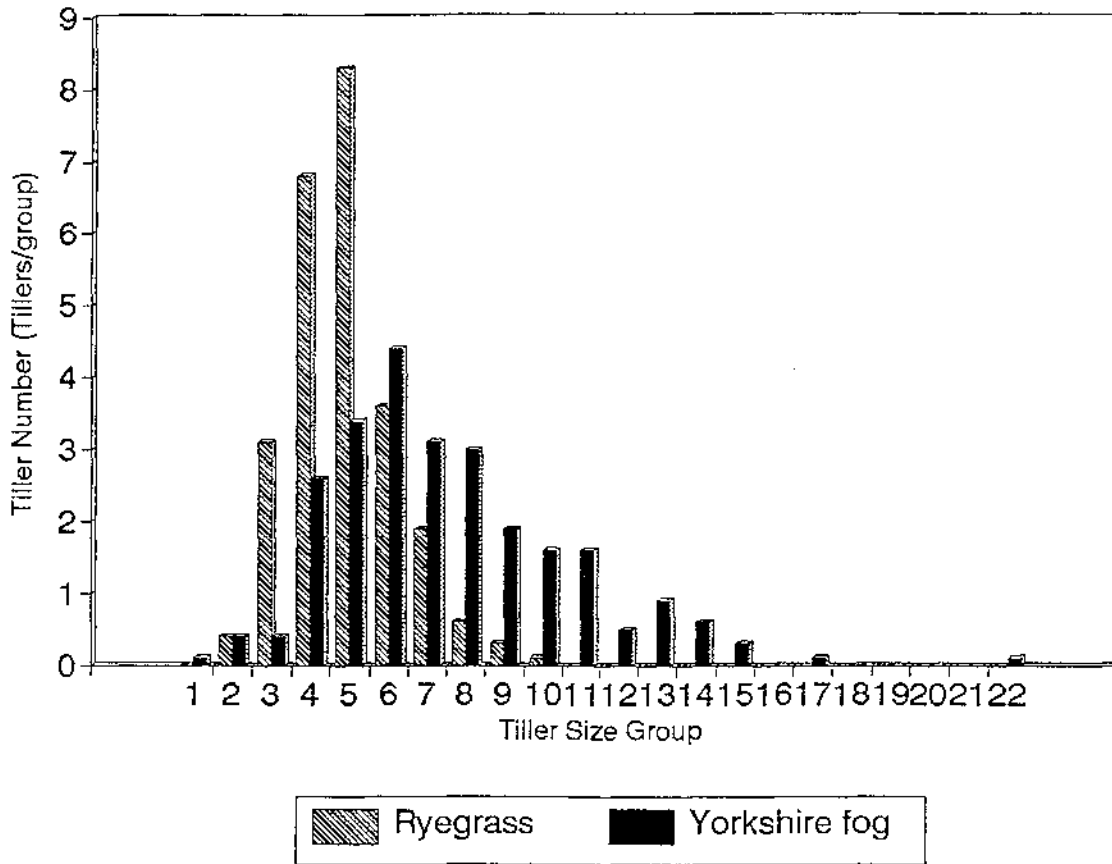
### **4.3. Tiller and node size distribution and population density**

#### **4.3.1. Size**

Analysis of the distribution of tiller size, based on pseudo-stem length as an index (Figure 4.1), showed that the tiller size of ryegrass were more evenly distributed around the mean. The range of pseudo-stem length was 10-99 mm in ryegrass, but 9-219 mm in yorkshire fog with a much more strongly skewed distribution.

#### **4.3.2. Population**

Tiller and node population density results are given in Table 4.4 and Figure 4.2. Tiller density of yorkshire fog in yorkshire fog/white clover pastures was higher than that of ryegrass in ryegrass/white clover pastures. White clover nodes maintained a very similar population density in both pastures. The tiller density of other grasses was substantial in both swards, but the value was significantly higher in ryegrass/white clover pasture than in yorkshire fog/white clover pasture. The population density of weeds was similar in both swards. Unit total populations in the two swards was very similar.



**Figure 4.1. Tiller size distribution of ryegrass and yorkshire fog**

Range of size: Pseudo-stem length (cm)

1: 0-9	9: 80-89	17: 160-169
2: 10-19	10: 90-99	18: 170-179
3: 20-29	11: 100-109	19: 180-189
4: 30-39	12: 110-119	20: 190-199
5: 40-49	13: 120-129	21: 200-209
6: 50-59	14: 130-139	22: 210-219
7: 60-69	15: 140-149	
8: 70-79	16: 150-159	

**Table 4.4. Tiller and node population density in ryegrass/white clover and yorkshire fog/white clover pastures (tillers or nodes/m<sup>2</sup>, data based on tiller and node separation)**

	Ryegrass/white clover pasture	yorkshire fog/white clover pasture	SEM
Sown grass tillers	6505	10355	918.7 **
White clover nodes	2365	2680	439.7 NS
Other grass tillers	8545	5088	373.3 **
Weeds	232	164	48.7 NS
Total	17647	18287	---

#### 4.4. Sward composition and structure

##### 4.4.1. Tiller and node dissection results

Data in Table 4.5.a showed that the mean pseudo-stem length per tiller before grazing was substantially greater in yorkshire fog than in ryegrass ( $p < 0.05$ ). There was no significant difference in stem weight and leaf number per tiller, leaf length or leaf weight per leaf between the two species and two grazing allowances, though ryegrass tillers had longer and heavier leaves than yorkshire fog. After grazing, stem length remained greater in fog than ryegrass ( $p < 0.05$ ). Leaf length and weight per leaf were greater in ryegrass than fog, though the differences were not significant. During

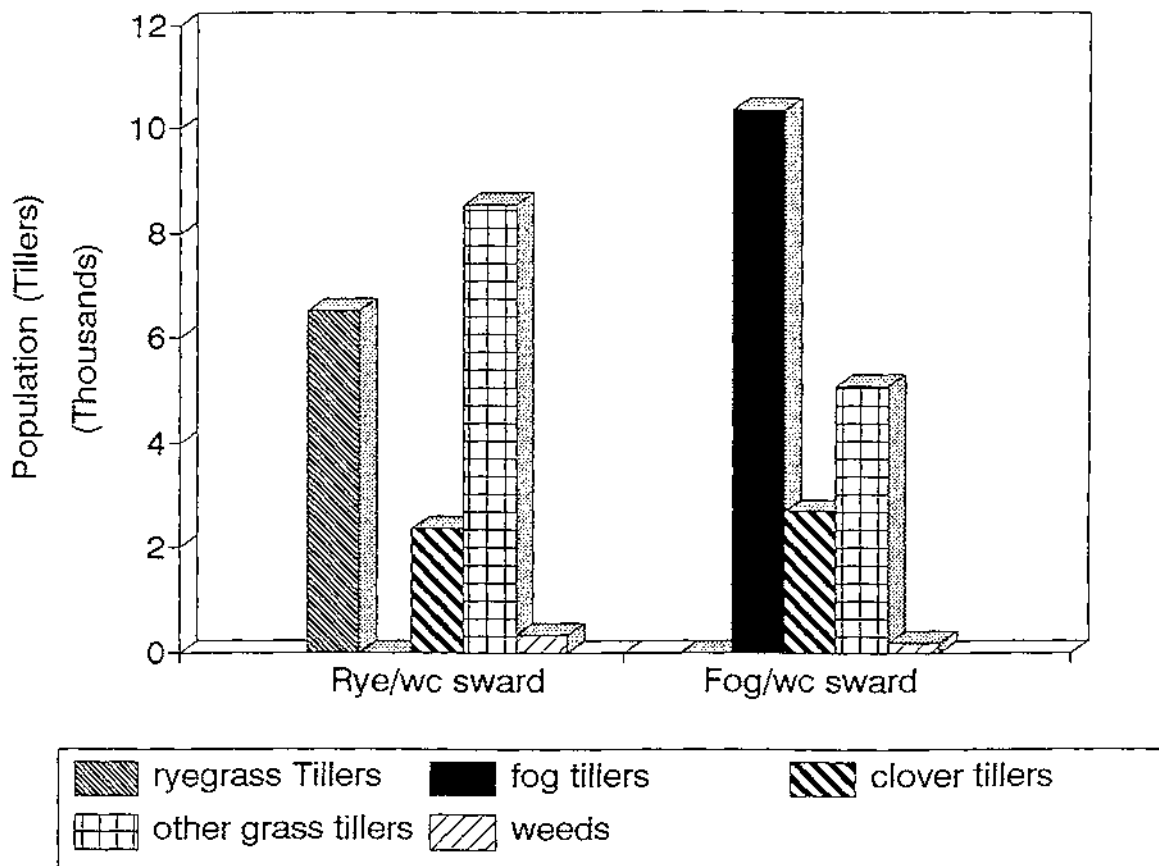


Figure 4.2. Tiller and node population in ryegrass/white clover and yorkshire fog/white clover pastures

grazing 48% and 46% leaf length was defoliated from ryegrass and yorkshire fog tillers respectively. Leaf number was significantly lower after grazing ( $p < 0.05$ ) at medium allowance.

White clover nodes were quite similar in, leaf number, leaf area and leaf weight between the species and allowances, both before and after grazing (Table 4.5.b). Leaf number was significantly decreased after grazing in yorkshire fog but not in ryegrass swards. The proportion of white clover leaf lost was higher in yorkshire fog/white clover pastures than in ryegrass/white clover pastures (17% vs. 6%). White clover petiole in yorkshire fog/white clover pasture showed greater length and weight values than clover petiole in ryegrass/white clover pasture though differences were not significant. There were no significant interactions between species and allowances.

#### **4.4.2. Canopy structure**

##### **4.4.2.1. Structure before grazing**

Point quadrat data (Table 4.6.(a)) showed that proportion of live sown grasses, clover and other grasses were all higher in ryegrass/white clover pastures than in yorkshire fog/white clover pastures before grazing, but the proportion of dead material was higher in yorkshire fog/white clover pastures. Yorkshire fog was recorded in ryegrass/white clover pasture in the point quadrat measurements, though no yorkshire

**Table 4.5.a. Tiller dissection results of ryegrass and yorkshire fog in ryegrass/white clover and yorkshire fog/white clover pastures respectively**

Before Grazing						
Mean value (per stem/leaf)	Species			Allowance		
	Ryegrass tiller	Yorkshire fog tiller	SEM	Medium allowance	High allowance	SEM
Stem length/per tiller (mm)	35.0	62.3	2.8 **	48.8	48.4	3.4 NS
Stem weight/per tiller (mg)	11.0	12.0	1.0 NS	11.0	12.0	0.7 NS
Leaf number/per tiller	3.0	2.9	0.1 NS	2.9	3.0	0.1 NS
Leaf length/per leaf (mm)	96.2	79.6	5.1 NS	89.5	86.3	6.2 NS
Leaf weight/per leaf (mg)	9.0	7.0	0.4 NS	8.0	8.0	3.0 NS
After Grazing						
Mean value (per stem/leaf)	Species			Allowance		
	Ryegrass tiller	Yorkshire fog tiller	SEM	Medium allowance	High allowance	SEM
Stem length/per tiller (mm)	37.0	51.9	2.6 *	41.8	47.1	3.2 NS
Stem weight/per tiller (mg)	13.0	12.0	2.0 NS	12.0	13.0	0.8 NS
Leaf number/per tiller	2.6	2.7	0.1 NS	2.4	2.9	0.1 *
Leaf length/per leaf (mm)	49.9	42.4	4.2 NS	40.4	51.8	6.4 NS
Leaf weight/per leaf (mg)	6.0	5.0	0.6 NS	4.0	6.0	0.6 NS

Table 4.5.b. Node dissection results of white clover in ryegrass/white clover and yorkshire fog/white clover pastures respectively

Before Grazing						
Mean value (per leaf/petiole)	Species			Allowance		
	Clover in ryegrass	Clover in yorkshire fog	SEM	Medium allowance	High allowance	SEM
Petiole length (mm)	32.6	37.4	3.3 NS	34.4	35.6	3.3 NS
Petiole weight (mg)	1.4	1.7	0.2 NS	2.0	2.0	0.2 NS
Leaf numbers/node	3.1	2.8	0.1 NS	2.9	3.0	0.1 NS
Leaf area (cm <sup>2</sup> )	0.9	0.9	0.1 NS	0.9	0.9	0.1 NS
Leaf weight (mg)	2.6	2.0	0.3 NS	3.0	2.0	0.2 NS
After Grazing						
Mean value (Per leaf/petiole)	Species			Allowance		
	Clover in ryegrass	Clover in yorkshire fog	SEM	Medium allowance	High allowance	SEM
Petiole length (mm)	30.6	35.1	0.8 NS	32.2	33.5	3.0 NS
Petiole weight (mg)	1.5	1.7	0.2 NS	1.4	1.8	0.2 NS
Leaf numbers/node	2.9	2.3	0.1 *	2.6	2.6	0.1 NS
Leaf area (cm <sup>2</sup> )	0.8	0.7	0.1 NS	0.7	0.8	0.1 NS
Leaf weight (mg)	1.9	1.6	0.2 NS	1.4	2.1	0.2 NS

fog appeared in hand separation of ryegrass/white clover samples. Less fog was recorded in ryegrass/white clover pastures than ryegrass in fog/white clover pastures. Other grasses and weeds were recorded in small proportions both before and after grazing. The relative proportion of grasses to clover was higher after grazing than before grazing. The increase was 7% for ryegrass/white clover and 4% for yorkshire fog/white clover pastures. White clover contacts decreased by similar proportions after grazing in both pastures (42% vs. 40%). The proportions of other grasses were higher after grazing than before grazing.

The proportions of white clover in both ryegrass/white clover and fog/white clover pastures were lower after grazing than before grazing, the reduction being slightly higher in ryegrass/white clover pastures. This result was different from tiller/node dissection results, where the loss of white clover leaf during grazing was higher in yorkshire fog/white clover pasture (Section 4.4.1).

The proportion of dead material (Table 4.6.(a)) was higher after grazing in both ryegrass/white clover and yorkshire fog/white clover pastures, but the increase was greater in fog/white clover pastures than in ryegrass/white clover pastures.

There was a tendency for grass leaf proportions to decrease and stem proportions to increase during grazing, the leaf decline being greater in ryegrass than in fog (Table 4.6.(b)). The proportion of clover leaf relative to petiole in ryegrass/white clover pastures increased 12% after grazing, but it decreased by 11% in fog/white clover

pastures.

#### 4.4.2.2. Defoliation height

Table 4.7.(a) shows mean values of the highest point quadrat contacts for grass and clover in the plots before and after grazing (more detailed information is listed in Appendix Table 1). The heights of defoliation for clover in ryegrass/white clover pasture and fog/white clover pasture were consistent, the values at both medium and high allowance being 3 cm for clover in ryegrass/white clover pasture and 5 cm for clover in fog/white clover pasture. On the other hand, the height of grazing for sown grasses obviously differed from that of white clover. The defoliated height differed between grazing allowances for grasses, but not clover (Appendix Table 1). Therefore, 3 cm and 5 cm from ground level were taken as the basal grazed stratum heights for clover in ryegrass/white clover and fog/white clover pastures respectively.

Overall, only 5.6% of contacts were recorded as clover above 3 cm from ground level in ryegrass/white clover pastures before grazing, while 8.5% contacts were recorded as clover above 5 cm in yorkshire fog/white clover pastures before grazing. The corresponding values for ryegrass and yorkshire fog were 91.8% and 80.5% (Figure 4.3, Table 4.7.(b)). Proportions of white clover and other grass species above grazed height in fog/white clover pasture were higher than those in ryegrass/white clover pasture. Measured grazed height fell by 41% and 59% for ryegrass and fog during grazing and by 50% and 72% for white clovers in the corresponding pastures. The

surface height of the grazed stratum was lower for white clover than the corresponding sown grasses after grazing.

When comparison was made between the proportions of above ground level and above grazed strata heights (Table 4.6.(a) and Table 4.7.(b)), there was a tendency for higher proportions of sown grasses and other grasses and lower proportions for white clover in grazed strata than in the whole canopy.

In addition, the height of vertical distribution of dead material (Table 4.7.(c)) in ryegrass/white clover pasture was lower than that of yorkshire fog/white clover pastures before grazing (9 cm vs. 13 cm). Those heights decreased in all treatments after grazing.

**Table 4.6. Botanical composition of ryegrass/white clover and yorkshire fog/white clover pastures determined from inclined point quadrat contacts (proportion of total point hits)**

(a) Overall proportions of sward components								
Treatments	Ryegrass	Clover in ryegrass	Yorkshire fog	Clover in fog	Other grasses	Weeds	Total live (%)	Dead material (%)
Ryegrass before grazing	81.1	13.7	2.5	--	2.4	0.3	91.2	8.8
Ryegrass after grazing	88.4	8.0	--	--	3.7	--	86.4	13.7
SEM	3.5 NS	2.5 NS	--	--	0.9 NS	--	1.9 NS	1.8 NS
Yorkshire fog before grazing	11.5	--	76.7	11.5	0.9	0.3	87.9	12.1
Yorkshire fog after grazing	8.9	--	80.4	6.9	3.8	--	76.0	24.0
SEM	0.9 NS	--	2.2 NS	1.4 NS	1.2 NS	--	1.1 **	1.1 **

(b) Leaf proportions of main species (compared with stem/petiole)

Grazing	Ryegrass	Clover in ryegrass	Yorkshire fog	Clover in fog
Before grazing	84.3	56.5	80.3	93.4
After grazing	72.7	68.9	77.5	85.4
SEM	4.4 NS	12.5 NS	1.8 NS	1.8 NS

(SEM calculated from Student t test)

**Table 4.7. Comparison of recorded basal grazing height for grass and clover components and proportions of botanical components above grazing height before and after grazing**

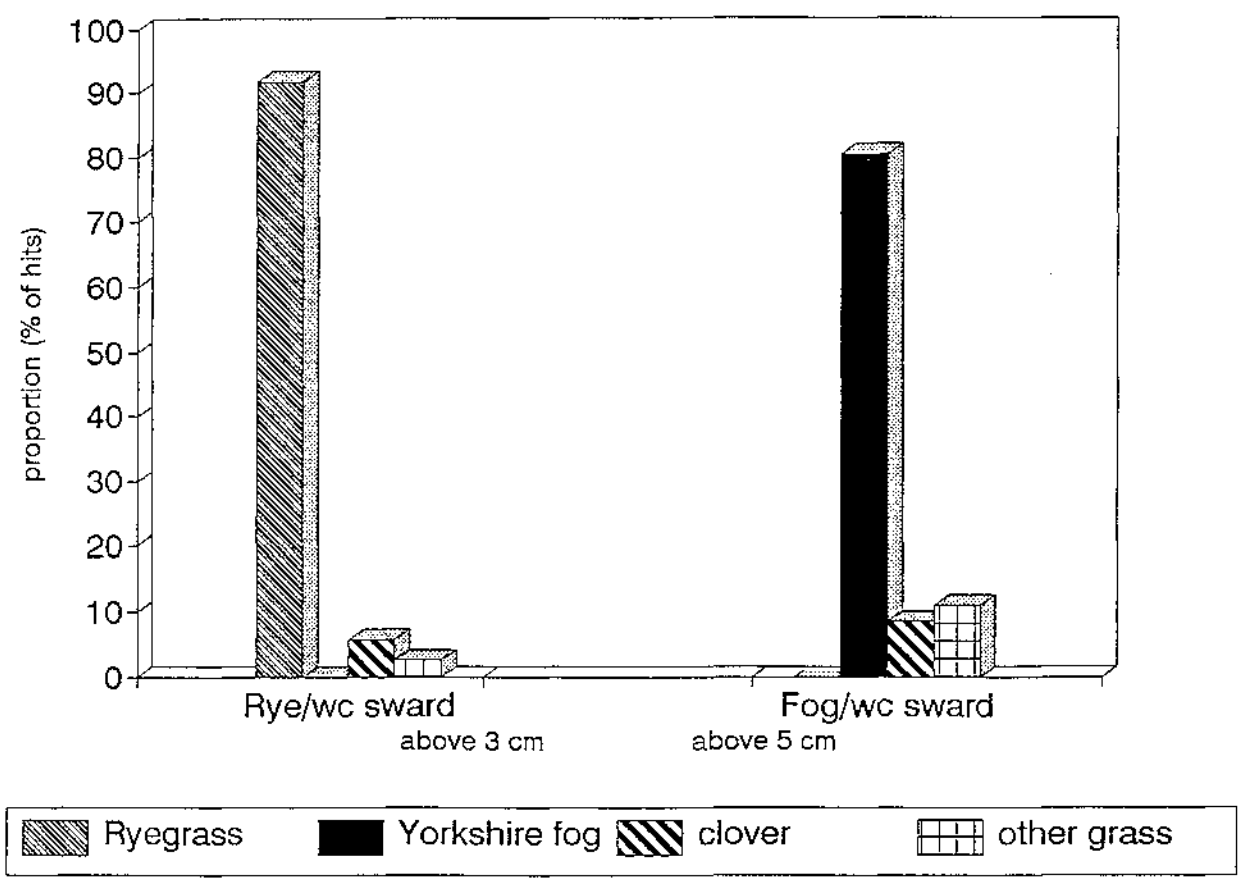
(a) Surface heights measured using inclined point quadrat (cm)				
Grazing	Ryegrass	Clover in ryegrass	Yorkshire fog	Clover in yorkshire fog
Before	17	6	23	9
After	10	3	12	5
SEM	3.3 NS	0.5 *	2.8 *	3.5 NS

(b) The proportions of live material in grazed strata before and after grazing (hits proportion of point quadrat)						
Grazing	Above 3 cm from ground level			Above 5 cm from ground level		
	Ryegrass	Clover in ryegrass	Other grass in ryegrass	Yorkshire fog	Clover in fog	Other grass in fog
Before	91.8	5.6	2.6	80.5	8.5	11.0
After	98.5	0.0	1.5	81.5	0.0	18.5

(c) The maximum height of contact with dead material in sward canopy (cm)				
Grazing	Ryegrass Medium allowance	Ryegrass high allowance	Yorkshire fog Medium allowance	Yorkshire fog high allowance
Before	3	15	14	12
After	5	11	6	10



**Figure 4.3. Proportion of components in grazed strata for ryegrass/white clover and yorkshire fog/white clover pastures**

## **4.5. Defoliation of marked tillers and nodes**

### **4.5.1. Defoliation parameters**

Estimates of defoliation were based on individual treatment values for: (i) the proportion of marked units which were defoliated (frequency); (ii) the proportion of leaf or stem (petiole) removed from grazed units (severity); (iii) the product of frequency x severity (= defoliation pressure). Statistical comparisons were then made: (a) between the grass and clover components within single plots, using individual transect values in a randomized block design; (b) between the grass and clover components within either ryegrass/white clover or yorkshire fog/white clover plots, using plot mean values in a 2 allowance x 4 replicates randomized block design; (c) between and within grass and legume components using all plot means in the original split-plot design.

All parameters were corrected to a daily basis for analysis.

The 'proportionate' analysis allows legitimate comparison between grass and legume, and different grasses, despite using different parameters (linear measurements for grass leaf and sheath, clover petiole; area estimates for clover leaf). No allowance was made for leaf growth over the defoliation period because this was quite short.

### **4.5.2. Defoliation results**

In the preliminary within-plot comparison, all three defoliation variables were consistently greater for the grass than the clover components. Plot mean values for each variable were used in the comparisons.

The frequency, severity and pressure of defoliation of leaf and stem/petiole, analyzed among ryegrass/white clover plots and among yorkshire fog/white clover plots separately, are presented in Table 4.8. In ryegrass/white clover pastures, the defoliation of leaf was significantly higher for ryegrass than white clover for all three parameters. In the comparison within yorkshire fog/white clover pastures, the defoliation frequency was not different between grass and clover, but the severity of defoliation and defoliation pressure were again significantly higher for grass than clover.

Ryegrass stem was grazed more severely than white clover petiole in ryegrass/white clover pastures. On the other hand, defoliation parameters for yorkshire fog stems and white clover petioles in yorkshire fog/white clover pastures showed smaller and not significant difference.

There was a highly significant effect of allowance on leaf defoliation in ryegrass/white clover pastures, but the effect was less marked in yorkshire fog/white clover pastures. Grazing allowance effects on the defoliation of grass stem and clover petiole were significant only for the severity and pressure of defoliation in ryegrass/white clover pasture. Among the comparisons of allowances, only clover petiole in ryegrass/white clover pasture was defoliated more severely and suffered a higher

defoliation pressure than ryegrass stem ( $p < 0.05$ ) at high than at medium allowance, whereas the comparison of yorkshire fog stem and white clover petiole in both medium and high allowances had a similar pattern as appeared in the comparison of species.

The interactions of defoliation for leaf and stem or petiole between pasture species and grazing allowance are listed in Table 4.9. Interactions were significant for all leaf defoliation parameters in ryegrass/white clover pasture, and for leaf defoliation pressure in yorkshire fog/white clover pasture. No significant interactions appeared for stem/petiole defoliation except defoliation severity in ryegrass/white clover pasture.

The cross plots analysis results (Table 4.10) show significant differences in the frequency of defoliation between ryegrass and yorkshire fog leaves. More ryegrass leaf was grazed per day than yorkshire fog leaf. The proportion of leaf removed (severity) and the pressure of grazing were higher in ryegrass than in fog (66.8% vs. 59.8% and 62.1% vs. 51.9% respectively). When white clover in ryegrass/white clover pastures was compared with white clover in yorkshire fog/white clover pastures, there were no differences in any of the three defoliation parameters.

Grazing allowance had significant effects on leaf defoliation parameters. Those effects were greater at medium allowance than in high allowance. For all parameters, allowance effect were greater for grasses than clover. The interaction for leaf defoliation frequency was not significant, while the interactions were significant for

**Table 4.8. Comparison of defoliation of leaf and stem/petiole between pasture species and grazing allowance (Analyzed within R/C plots and F/C plots respectively)**

<u>(a) Species within ryegrass/white clover and yorkshire fog/white clover pastures</u>						
	Ryegrass/white clover pasture			Yorkshire fog/white clover pasture		
	Ryegrass	Clover	SEM	Yorkshire	Clover	SEM
Leaf:						
Defoliation frequency	11.0	8.5	0.38 ***	9.9	9.1	0.48 NS
Defoliation severity	8.4	6.2	0.31 ***	7.6	6.1	0.34 **
Defoliation pressure	7.7	4.2	0.28 ***	6.3	4.5	0.45 *
Stem or petiole:						
Defoliation frequency	7.6	4.0	0.67 **	7.1	6.6	0.61 NS
Defoliation severity	4.0	2.3	0.19 ***	3.9	3.5	0.30 NS
Defoliation pressure	2.5	1.0	0.15 ***	2.5	1.9	0.23 NS
<u>(b) Allowance effects within ryegrass/white clover and yorkshire fog/white clover pastures</u>						
	R/C medium			F/C Medium		
	R/C medium	R/C High	SEM	F/C Medium	F/C High	SEM
Leaf:						
Defoliation frequency	11.3	8.2	0.38 ***	10.8	8.3	0.483 **
Defoliation severity	8.4	6.3	0.31 ***	7.2	6.5	0.34 NS
Defoliation pressure	7.8	4.2	0.29 ***	6.4	4.4	0.45 **
Stem or petiole:						
Defoliation frequency	5.5	6.1	0.67 NS	7.1	6.6	0.61 NS
Defoliation severity	2.7	3.6	0.19 **	3.2	4.0	0.30 NS
Defoliation pressure	1.4	2.1	0.15 **	2.0	2.3	0.23 NS

**Table 4.9. Interactions of defoliation of leaf and stem/petiole between pasture species and grazing allowance (Analyzed within R/C plots and F/C plots respectively)**

Treatments	Leaf defoliation frequency	Leaf defoliation severity	Leaf defoliation pressure	Stem/petiole defoliation frequency	Stem/petiole defoliation severity	Stem/petiole defoliation pressure
R/C M	12.5	10.5	10.5	7.3	3.9	2.1
R/C H	9.5	6.4	4.9	7.9	4.1	2.8
C/R M	10.1	6.2	5.0	3.7	1.5	0.6
C/R H	6.9	6.2	3.4	4.3	3.1	1.3
SEM	0.54 ***	0.44 ***	0.40 **	0.94 NS	0.26 *	0.21 NS
F/C M	11.8	8.5	8.0	7.6	3.5	2.3
F/C H	8.1	6.8	4.5	6.6	4.0	2.5
C/F M	9.8	6.0	4.8	6.5	2.9	1.7
C/F H	8.5	6.2	4.2	6.6	4.0	2.2
SEM	0.67 NS	0.49 NS	0.63 *	0.86 NS	0.43 NS	0.33 NS

R/C: Ryegrass in ryegrass/clover sward

C/R: Clover in ryegrass/clover sward

F/C: Yorkshire in yorkshire fog/clover sward

C/F: Clover in yorkshire fog/clover sward

M: medium grazing allowance

H: High grazing allowance

Frequency of defoliation: % of defoliated tillers (in number) per day

Severity of defoliation: % of removed leaf (in length) per tiller per day

Pressure of defoliation: % of total removed amount of material on marked populations per day

defoliation severity and pressure ( $P < 0.01$  and  $p < 0.001$ ).

The analysis of results for stems and petioles (Table 4.11) showed that severity of defoliation varied in the comparisons between grasses and clovers. There were no significant differences between grasses. White clover petioles were more severely grazed in ryegrass/white clover pastures than the corresponding ryegrass stem. Yorkshire fog stem was grazed with a higher pressure of defoliation than ryegrass stem. The defoliation pressure for white clover petiole was greater than for ryegrass stem, which was similar to the result of defoliation severity. The defoliation of white clover petioles in both swards was similar. No significant difference showed in stem/petiole defoliation frequency.

The frequency, severity and pressure of defoliation of stem/petiole differed substantially between medium and high allowances ( $p < 0.001$ ).

No interactions were significant in the comparison between grass stems and clover petioles except defoliation severity.

More detailed comparisons of interaction for cross plots analysis are presented in Appendix Table 2.1; 2.2 and 2.3.

**Table 4.10. Comparison matrices of leaf defoliation frequency, severity and defoliation pressure among species and allowance (Analyzed across all plots)**

	Species					Allowance		Interactions species and allowance
	LSM	Ryegrass	Clover in ryegrass	Fog	Clover in fog			
<b>Defoliation frequency (% tiller/node per day)</b>								
Ryegrass	11.3					Medium	10.5	
Clover in ryegrass	8.2	***				High	8.8	
Yorkshire fog	10.8	*	NS			SEM	0.32 ***	
Clover in fog	8.3	***	NS	NS	--			
SEM	0.45 **							NS
<b>Defoliation severity (% leaf removed per day)</b>								
Ryegrass	8.4					Medium	8.0	
Clover in ryegrass	6.3	***				High	6.2	
Yorkshire fog	7.2	*	NS			SEM	0.24 ***	
Clover in fog	6.5	***	NS	NS	--			
SEM	0.34 ***							**
<b>Defoliation pressure (% total leaf removed on defoliated tillers per day)</b>								
Ryegrass	7.8					Medium	7.0	
Clover in ryegrass	4.2	***				High	4.4	
Yorkshire fog	6.4	*	***			SEM	0.27 ***	
Clover in fog	4.4	***	NS	***	--			
SEM	0.39 NS							***

**Table 4.11. Comparison matrices of stem/petiole defoliation frequency, severity and defoliation pressure among species and allowance (Analyzed across all plots)**

Defoliation frequency (% stem/petiole per day)	LSM	Species				Allowance		Interaction s species and allowance
		Ryegrass	Clover in ryegrass	Fog	Clover in fog			
Ryegrass	5.5					Medium	10.5	
Clover in ryegrass	6.1	NS				High	8.8	
Yorkshire fog	7.1	NS	NS			SEM	0.32 ***	
Clover in fog	6.6	NS	NS	NS	--			NS
SEM	0.60 NS							
<hr/>								
Defoliation severity (% stem/petiole removed per day)								
Ryegrass	2.7					Medium	8.0	
Clover in ryegrass	3.6	*				High	6.2	
Yorkshire fog	3.2	NS	NS			SEM	0.24 ***	
Clover in fog	4.0	***	NS	*	--			**
SEM	0.24 **							
<hr/>								
Defoliation pressure (total stem/petiole removed on defoliated tillers per day)								
Ryegrass	1.4					Medium	7.0	
Clover in ryegrass	2.1	**				High	4.4	
Yorkshire fog	2.0	*	NS			SEM	0.27 ***	
Clover in fog	2.3	***	NS	NS	--			NS
SEM	0.11 **							

## **CHAPTER 5. DISCUSSION**

### **5.1. Introduction**

In this chapter, pasture mass, sward height, tiller and node size and population density, and botanical composition are firstly compared to provide background information. The defoliation data are discussed in terms of the comparisons between grass and clover in the sown swards, between grass components in both swards, and grass/clover balance in each case. Finally the interactions between the effects of sward structure and preferential grazing on the defoliation of grass and clover are discussed.

### **5.2. Comparison of sward conditions**

#### **5.2.1. Herbage mass and sward height**

The reaction of the grass sward to defoliation is principally determined by the position of its component organs in relation to the height of defoliation (Davies, 1988). The pastures used in this experiment were pre-treated uniformly according to the similar values for height and mass before grazing (Table 4.1 and Table 4.2). The significant difference between allowances in pre-grazing height estimated inside

quadrats was probably a chance effect, as estimates made outside quadrats did not differ (Table 4.2).

The surface heights of swards measured both inside and outside quadrats matched very closely (Table 4.2). Thus either measurement could be used when sward height measurements are conducted by using sward sticks, particularly when both height and mass estimates are needed.

There was some co-relationship between the sward surface heights measured by sward stick and inclined point quadrat. Most of the corresponding values are similar (Table 5.1). The indication is that the measurements of height can be conducted using either point quadrat or sward stick. When sward structure data is necessary, sward height can be estimated simultaneously using point quadrat data.

Results in the present study have shown that herbage accumulation rates for ryegrass/white clover pasture and yorkshire fog/white clover pasture were similar, as shown by many authors including Watkin and Robinson (1974), Jacques et al (1962).

The herbage mass removed during grazing was higher from ryegrass/white clover than from yorkshire fog/white clover pastures (1148, 620, 980, and 589 kg DM / ha respectively from R/CM, R/CH, F/CM and F/CH). Differences were greater in proportionate basis (Table 4.1) because pre-grazing herbage mass was lower on ryegrass/white clover than on yorkshire fog/white clover, but this may suggest that

ryegrass/white clover pastures were preferred by sheep. Watkin and Robinson (1974) showed the relatively low acceptability of yorkshire fog at some stages of growth compared with ryegrass. The higher proportion of dead material may also have contributed to the higher post-grazing residuals on yorkshire fog than on ryegrass plots (Table 4.3 and 4.7).

**Table 5.1. Comparison of sward surface height measured using point quadrat and sward stick (cm)**

Measure- ment	Grazing	Ryegrass	Ryegrass	Fog	Fog
		medium	high	medium	high
Point quadrat	Before	9.0	13.5	15.0	17.0
	After	5.0	8.0	7.0	8.5
Sward stick	Before	12.8	13.6	12.3	14.2
	After	5.7	8.9	6.8	8.9

### 5.2.2. Tiller and node size, and population density

Yorkshire fog tillers had longer and heavier pseudo stem, similar leaf number but less individual leaf length and weight (NS) than ryegrass. They also had higher population density (Table 4.4 and Table 4.5.a). There were obvious differences in size distribution patterns for ryegrass and yorkshire fog tillers (Figure 4.1). This may have

influenced the vertical structure of the sward canopies.

The significantly higher population of yorkshire fog tillers in the sward might provide more shade to lower layers and as a result, more dead matter in yorkshire fog/white clover than in ryegrass/white clover pastures (Table 4.3). This case will be supported by point quadrat data in the following sections.

The tillers of other grasses were much smaller and distributed in lower layer of the sward canopy. *Poa annua* tillers formed the major component of other grasses. Bircham and Hodgson (1983) reported that the laminae of *Poa* tillers occupied an inferior position in the canopy of mixed-species swards of *Lolium perenne*, *Poa annua* and *Trifolium repens* and were less accessible to the grazing animals. Thus the *poa* tissue was less utilized.

### 5.2.3. Botanical composition

Pasture morphology data showed that yorkshire fog stem was longer but not heavier than ryegrass before and after grazing (Table 4.5.a) indicating a greater weight per unit length for ryegrass than fog stem. Ryegrass stem length increased slightly after grazing which may be because of the lower distribution in the sward canopy and of the lower chance of defoliation. Such evidence is also available in point quadrat results (Table 4.7, Appendix Figure 1-4) which showed that the grazed height of ryegrass was above 10 cm from ground level, much higher than the distribution of

stems. The opposite was the case for fog stem, which was distributed in higher levels of the canopy and was defoliated to a greater extent during grazing. Leaf length results provide more evidence for the difference in defoliation rate between the sown grasses. Longer and slightly heavier leaves in ryegrass formed the major components in the grazed strata and therefore were grazed more severely than was yorkshire fog leaf. Leaf numbers for both grasses were similar before grazing, but during grazing more leaves were removed on ryegrass than on yorkshire fog tillers. The greater leaf defoliation may delay regrowth in ryegrass, but further comparison is necessary to evaluate the relationship between defoliation rate and regrowth in ryegrass and yorkshire fog. Though yorkshire fog stems were grazed, the mean leaf number per tiller were still maintained at a higher value than ryegrass. This probably was due to the uneven tiller size of yorkshire fog, and as a result smaller tillers were less defoliated.

The presence of more leaves and greater individual leaf length on ryegrass than on fog tillers (Table 4.5.a) may explain why ryegrass plots were grazed to a lower residual than fog plots, though the surface heights after grazing were similar. It is reasonable to suggest that more ryegrass leaf was removed close to ground level in ryegrass/white clover pastures than in fog/white clover pastures, and as a result, pasture density was reduced. However, information on population density data after grazing would be needed to confirm this suggestion.

The fact that more clover leaf was maintained after grazing in ryegrass/white clover

pastures than in fog/white clover pastures (table 4.5.b) may be because clover leaf in ryegrass pastures was vertically distributed lower and less accessible to the animal (Appendix Figures). The petiole length of clover in yorkshire fog/white clover pasture was longer than in ryegrass/white clover pastures, though the difference was not significant (Table 4.5.b). This indicates that white clover in yorkshire fog/white clover pasture could be better utilized by the animals because of its higher vertical distribution in the sward canopy.

The higher proportion of unsown species in ryegrass plots was not consistent with the results of other research (Watkin and Robinson, 1974; Harvey et al, 1984; Watt, 1987) where Massey Basyn were more prone than ryegrass to invasion by unsown species (Morton et al, 1992).

### **5.3. Evaluation of defoliation results**

#### **5.3.1. Comparison between grass and clover defoliation in each sward**

The frequency and severity of defoliation of populations of marked units for each species were defined as '% of each population of marked units grazed per day' and '% of leaf removed from grazed units per day' by Bootsma et al (1990). Their definitions are also used here. The product of frequency and severity of defoliation is here defined as defoliation pressure.

The result of the within ryegrass/white clover plots analysis (Table 4.8) showed that ryegrass leaf was defoliated more frequently, severely and with higher pressure than clover leaf. Ryegrass leaf formed the major proportion and occupied the upper layer of the sward canopy, and therefore was more accessible to the sheep. This result agrees with the results of Bootsma et al (1990), who found that the frequency of defoliation of white clover was lower than that of perennial ryegrass in plots grazed by deer. Results for severity of defoliation followed a similar pattern. On the other hand, yorkshire fog leaf and clover leaf were defoliated at a similar frequency (Table 4.8). Clover leaves were distributed within the grazed strata of yorkshire fog/white clover pasture and accessible to the animals (Appendix Figure 5-8). The higher vertical distribution of clover leaf in yorkshire fog/white clover swards reflects the longer petioles in these swards. The above results can be confirmed by tiller dissection data (Table 4.5) and point quadrat data (Table 4.7). The higher defoliation severity and pressure in yorkshire fog leaf than the corresponding white clover leaf were similar to the comparison of ryegrass and white clover.

Allowance effects on grazing frequency and pressure were greater for both ryegrass and yorkshire fog leaves than for the companion clover (Table 4.8.(b)), again reflecting the vertical distribution of foliage (grass mainly in upper strata). The lack of an effect of allowance on grazed height of clover was unexpected. The significant effect of allowance on ryegrass leaf defoliation in ryegrass/white clover pastures may be considered to result from the higher accessibility of ryegrass to the sheep and preferential grazing, but this needs to be confirmed by herbage intake data.

Defoliation severity was not sensitive to grazing allowance for yorkshire fog or for clover leaves, which suggests that the proportion of yorkshire fog/white clover leaves removed during grazing was similar both at medium and high allowances. However, leaves in yorkshire fog/white clover swards were more frequently defoliated and with higher defoliation pressure at medium allowance than at high allowance; this supports the stronger effect of grazing allowance on grass than on clover.

The comparison of defoliation between grass stem and clover petiole at medium and high allowance reflected a very similar pattern to the comparison for leaves. Significant differences in defoliation severity and pressure for ryegrass stem and clover petiole suggest that the different distribution patterns in the mixed swards reflected different effects of defoliation by sheep. Smaller differences were shown between yorkshire fog stem and clover petiole in such comparisons.

### **5.3.2. Comparison between grass components and grass/clover balance in swards**

The comparison of cross plots analysis strongly suggested that ryegrass leaves were defoliated more severely than yorkshire fog leaves in all three parameters of defoliation (Table 4.10). However, there were no significant differences between clover leaves in ryegrass/white clover and yorkshire fog/white clover pastures. Yorkshire fog stems (Table 4.11) were grazed more severely, though not more frequently than ryegrass stems. All of the defoliation parameters were similar for white clover petioles in ryegrass/white clover and yorkshire fog/white clover swards.

Botanical composition results showed that the proportion of dead material was higher in yorkshire fog/white clover pastures than in ryegrass/white clover pastures both before and after grazing, though the differences were only significant after grazing (Table 4.3). It is not clear whether the higher proportion of dead material in yorkshire fog is due to slower decomposition. Higher condensed tannin (CT) concentration in yorkshire fog leaf and stem tissue than in ryegrass (Terrill et al, 1992) may inhibit tissue breakdown. The larger proportion of dead material and the longer stem for yorkshire fog may have contributed to selective grazing in the yorkshire fog/white clover pastures. Clark et al (1982) suggested that rejection of pseudo stem and dead material may be related to a low preference ranking and/or inaccessibility.

The fact that the proportion of ryegrass decreased while fog increased after grazing in the data of hand separation did not match the results of point quadrat data, which showed that the proportions for both grass species were greater after grazing than before grazing. This difference of proportions may be due to the different dimensions of measurement in which DM weight and point hits were used respectively.

The proportion of white clover was very similar in yorkshire fog/white clover pastures before and after grazing (5% in each case, Table 4.3). This suggests that white clover in yorkshire fog swards was easily maintained due to the higher herbage density in lower strata of the sward which may protect white clover from selected grazing by the animals to some degree. Similarly, L'Huillier and Poppi (1984)

reported that defoliation of white clover was influenced by the vertical distribution of leaf. There was a higher proportion of white clover in ryegrass/white clover pastures than in yorkshire fog/white clover pastures after grazing, though the difference was not significant (Table 4.3).

### 5.3.3. Defoliation and sward structure

In this study, grass was more severely defoliated than clover in both swards. There was a close relationship between defoliation and sward structure. The greater defoliation of grass than clover in the mixed swards may be explained largely by the larger proportion and higher level of the vertical distribution in the sward canopy. All those results could be explained by sward structure data drawn from point quadrat analysis (Table 4.7). The greater surface heights for grasses provide greater opportunity for defoliation than clover.

The depth of the grazed stratum (termed bite depth) was largely determined by the post-grazing heights of white clover and sown grasses respectively. The proportions of components within grazed strata were assessed separately by using appropriate grazing heights for ryegrass/white clover and fog/white clover pastures which reflected the basal level of defoliation of clover in each case.

The grazed heights for defoliated clover were the deepest penetration of the animals within the swards. This information could be used to estimate the defoliation patterns.

Thus grazed stratum heights above 3 cm and 5 cm from ground level were used in this section corresponding to the relative white clover residual heights in ryegrass and yorkshire fog pastures respectively.

The higher proportion of grasses after grazing than before grazing in point quadrat data (Table 4.6) could be largely due to the decreasing of clover components. The decreased proportion of yorkshire fog in ryegrass/white clover pastures and ryegrass in fog/white clover pastures, and weed also made some contribution to such a increase of sown grass proportions. It is to be expected that the proportion of grass leaves would decrease after grazing while stem proportions increased in the point quadrat analysis. The leaf proportion was higher for ryegrass than fog, which were consistent with the previous results of longer leaf, and more severe defoliation rate for ryegrass in Section 4.4.1.

The point quadrat data indicated that the presence of dead material extended to higher levels in the yorkshire fog/white clover sward than in the ryegrass/white clover sward (13 vs. 9 cm; Table 4.7.(c)). This might also have had some influence on grazed strata heights. However, less difference was apparent after grazing. This data suggested that dead material in yorkshire fog/white clover swards was not only in higher proportion but also distributed vertically higher than ryegrass/white clover swards before grazing. Furthermore, some dead material was distributed in the grazed strata in both swards, and the proportion was much higher in yorkshire fog/white clover pasture than in ryegrass/white clover.

The reduced height of distribution of dead material in the sward canopy after grazing may have been due to the trampling of the animals.

#### **5.4. Selective defoliation**

Comparing the sown grasses in this study, ryegrass was defoliated more severely than yorkshire fog (Table 4.10). The results indicate that this effect was attributed largely to differences in the relative proportion and vertical distribution of the grass and legume components of the two swards, rather than to any inherent differences in palatability between the two grasses.

There was a strong tendency of selective grazing towards white clover by sheep in the experiment when comparing the residual heights of grasses and clover (Table 4.7.(a)). In ryegrass/clover pastures the mean basal values for ryegrass and clover were 10 cm and 3 cm after grazing, whereas the values for yorkshire fog and clover in yorkshire fog were 12 cm and 5 cm respectively. Thus white clover was grazed closer to ground level than the two grass species. The mean grazed height for clover in the experiment of Bootsma et al (1990) was 4 cm from ground level.

The results of the pasture studies of Bootsma et al (1990) indicated that, in proportionate terms, clover was subjected to a severity of defoliation which was at least equal to that of grasses, despite the fact that clover foliage was carried lower and well protected by grass in the sward canopy. Those statements were supported

by the results of the present study. The implication is that the animals were discriminating actively for clover. Furthermore, the generally lower defoliation height for clover than for grass provides a real explanation for the lower disposition of clover foliage within the canopy. Clark and Harris (1985) suggested that more information would be required on the degree of aggregation of grass and clover within the pasture, and the vertical distribution of grass leaf lamina and stem relative to clover lamina and petiole (Bootsma et al, 1990).

The vertical distribution of white clover relative to the major dietary component (grass leaf) rather than animal preference may have influenced its consumption by sheep in the study. In the yorkshire fog/white clover sward white clover leaf was in closer vertical proximity to grass leaf and thus was accessible. However, much of the grass leaf in ryegrass/white clover swards was located higher than clover and as a result less grazing occurred in the horizon containing clover.

The point quadrat data in this study (Table 4.6; Table 4.7 and Appendix Figures) provided information on vertical distribution but not on the horizontal aggregation of grass and clover components.

The higher proportion of pasture mass removed during grazing on ryegrass/white clover than on yorkshire fog/white clover pastures may suggest that ryegrass was preferred by the sheep (Table 4.1). Other evidence to support this suggestion is that ryegrass pseudo stem was short and distributed under the grazed stratum and

therefore less accessible. Furthermore, longer and slightly heavier leaf in ryegrass formed the major components in the grazed stratum and was grazed more severely than was yorkshire fog. Yorkshire fog was defoliated in lower proportion, this may be because of its longer pseudo stem, higher tiller density, more dead material within the canopy, and higher condensed tannin (CT) concentration (Terrial et al, 1992) in the tissue.

Ryegrass leaf was defoliated more frequently, severely and with higher pressure than the clover leaf. On the other hand, yorkshire fog and the clover leaves were defoliated at similar frequencies (Table 4.8). Point quadrat results suggested that clover leaf in yorkshire fog swards was distributed within the grazed stratum (Appendix Figures) and accessible to the animals. Those facts indicate that the differences in sward structure were important in altering grazing patterns. The fact that allowance effects on grazing parameters were greater for both ryegrass and yorkshire fog leaves than for the companion clover again confirmed this importance.

## CHAPTER 6. CONCLUSIONS

The primary aim of this study was to evaluate selective defoliation through detailed sward measurements. The basic information on pasture mass, sward height, tiller and node size, population density and botanical composition provided the background to defoliation data. The parallel data on sward structure complemented the measurements of sward components and vertical distribution. These observations, together with the results of observations on marked tillers and nodes, provided the basic for estimating selective defoliation in the two swards.

Both ryegrass and yorkshire fog were defoliated more severely than the corresponding clovers. This effect was attributed largely to differences in the relative proportion and vertical distribution of the grass and legume components, rather than to any inherent differences in palatability between them. When comparison was made between the two grasses, ryegrass was preferentially defoliated by the sheep. Ryegrass leaf was defoliated to a greater extent than yorkshire fog leaf, whereas yorkshire fog stems were defoliated to a greater extent than ryegrass stems. Great leaf length and higher leaf proportion in ryegrass than in fog would provide advantages in preference and accessibility of ryegrass. In contrast, greater stem length and density, higher proportion of dead material and its higher vertical distribution in yorkshire fog may cause rejection and selective grazing by the animals. Other effects such as pubescence

and condensed tannin in yorkshire fog tissue might also reduce palatability, however this would need to be confirmed by further study.

Point quadrat results strongly indicated that white clover was defoliated closer to ground level than the companion grass in both swards. Therefore, despite the evidence on the lower composition of clover in grazed strata, the results are interpreted as indicative of active selection for clover by the sheep. The higher vertical distribution of white clover leaf in yorkshire fog/white clover pasture than in ryegrass/white clover pasture offered higher accessibility and thus a more severe defoliation.

Grazing allowance effects on grazing frequency and pressure were greater for both ryegrass and yorkshire fog than for the clover. The preferential defoliation of clover was also indicated by the base grazing level for the legume at both allowances.

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## APPENDICES

**Appendix Table 1. The comparison of recorded surface heights for grass and clover components among treatments before and after grazing (measured using point quadrat)**

Grazing	Ryegrass/white clover swards medium allowance		Ryegrass/white clover swards high allowance		Yorkshire fog/white clover swards medium allowance		Yorkshire fog/white clover swards high allowance	
	Ryegrass	Clover in ryegrass	Ryegrass	Clover in ryegrass	Yorkshire fog	Clover in yorkshire fog	Yorkshire fog	Clover in yorkshire fog
Before	13.0	5.0	20.0	7.0	21.0	9.0	25.0	9.0
After	7.0	3.0	13.0	3.0	9.0	5.0	14.0	5.0





**Appendix Table 2.3. Comparison matrices of stem/petiole defoliation frequency, severity and defoliation pressure among species, allowance and the interactions of species x allowance**

	LSM	RM	RH	C/RM	C/RH	FM	FH	C/FM	C/FH
Defoliation frequency of stem/petiole									
RM	7.3								
RH	3.7	**							
C/RM	7.9	NS	**						
C/RH	4.3	*	NS	**					
FM	7.6	NS	**	NS	*				
FH	6.5	NS	*	NS	NS	NS			
C/FM	6.6	NS	*	NS	NS	NS	NS		
C/FH	6.6	NS	*	NS	NS	NS	NS	NS	
SEM	0.85	NS							
Defoliation severity of stem/petiole									
RM	3.9								
RH	1.4	***							
C/RM	4.1	NS	***						
C/RH	3.1	NS	**	*					
FM	3.5	NS	***	NS	NS				
FH	3.0	NS	**	*	NS	NS			
C/FM	4.0	NS	***	NS	*	NS	*		
C/FH	4.0	NS	***	NS	NS	NS	*	NS	
SEM	0.33	**							
Defoliation pressure of stem/petiole									
RM	2.1								
RH	0.6	***							
C/RM	2.8	NS	***						
C/RH	1.3	*	NS	***					
FM	2.3	NS	***	NS	*				
FH	1.7	NS	**	**	NS	NS			
C/FM	2.5	NS	***	NS	**	NS	*		
C/FH	2.2	NS	***	NS	*	NS	NS	NS	
SEM	0.26	NS							

The corresponding units of defoliation frequency, severity and pressure are defined as table 4.9. respectively.

**Code for appendix figures:**

## (a) Abbreviation of treatments

R: Ryegrass/white clover pasture

F: Yorkshire fog/white clover pasture

M: Medium grazing allowance

H: High grazing allowance

B: Before grazing

A: After grazing

i.e. RMB refers to ryegrass/white clover pasture, medium allowance,  
before grazing

## (b) Group 1 and group 2 code for species and morphology

group 1 code: Species    group 2 code: morphology

R: Ryegrass            L: Leaf










F: Yorkshire fog      S: Stem

C: white clover      P: petiole

O: Other grasses

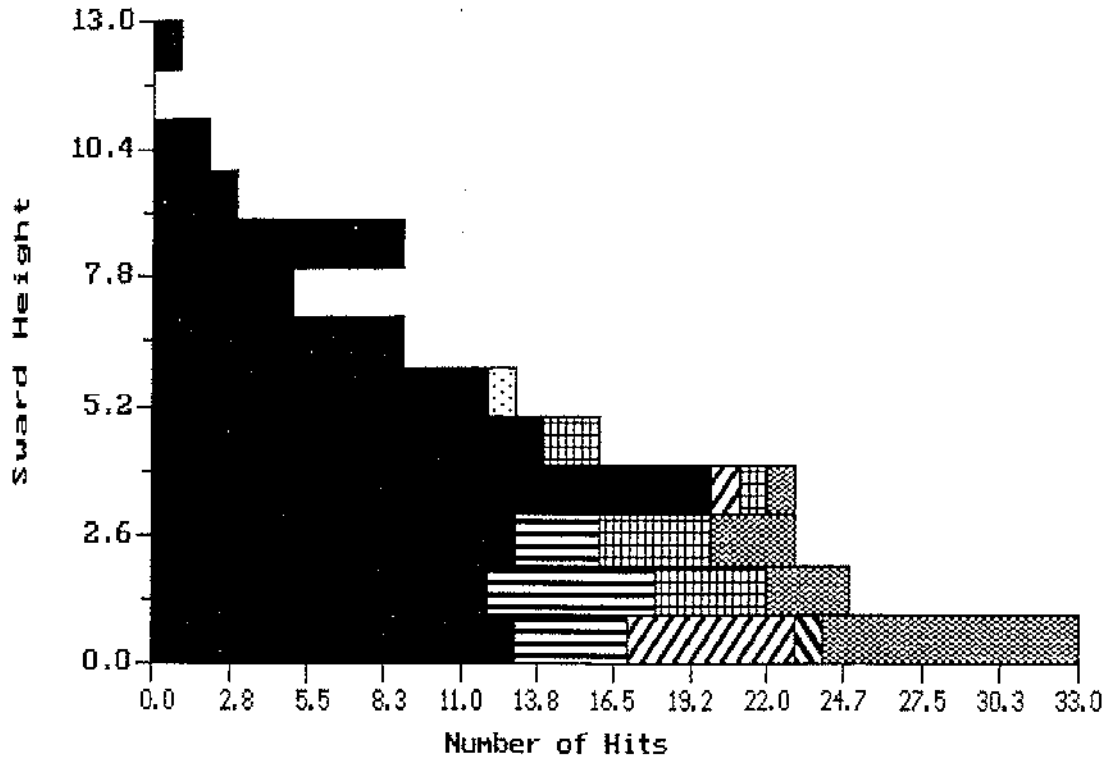
W: Weeds

(c) Key for figures of species and morphology

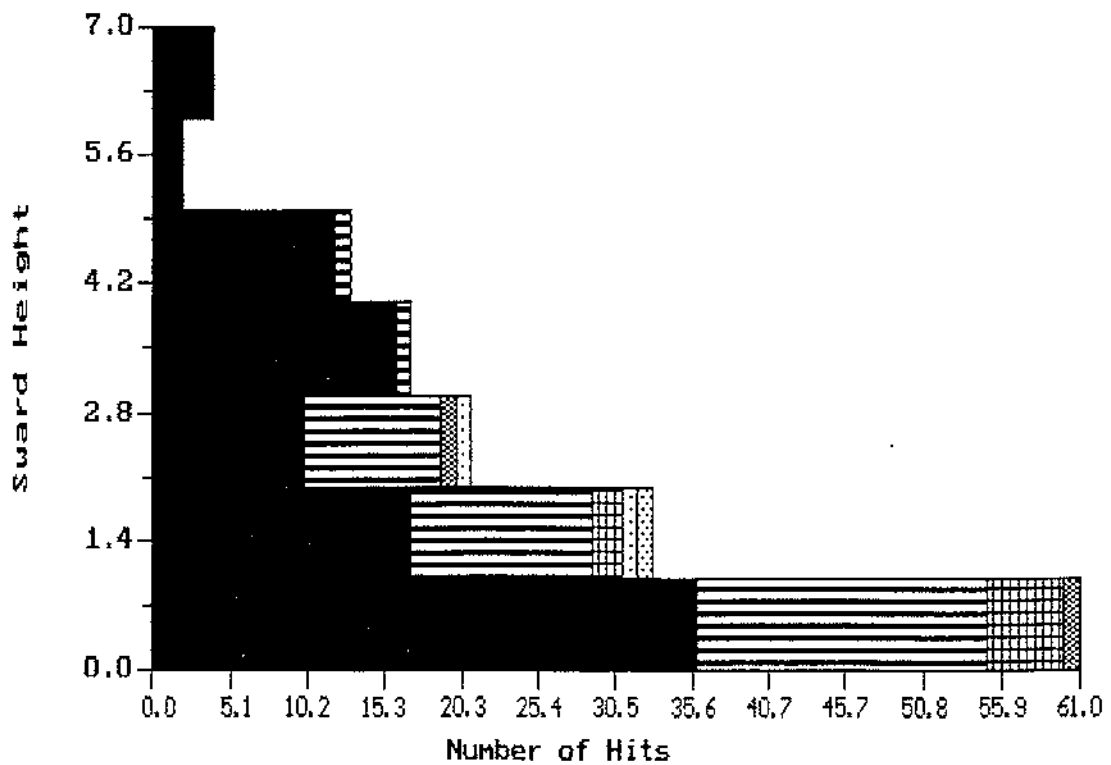
-  : Ryegrass leaf
-  : Ryegrass stem
-  : Yorkshire fog leaf
-  : Yorkshire fog stem
-  : White clover leaf
-  : White clover stem
-  : Other grasses leaf
-  : Other grasses stem
-  : Weeds

(d) The reported height interval is 1 cm

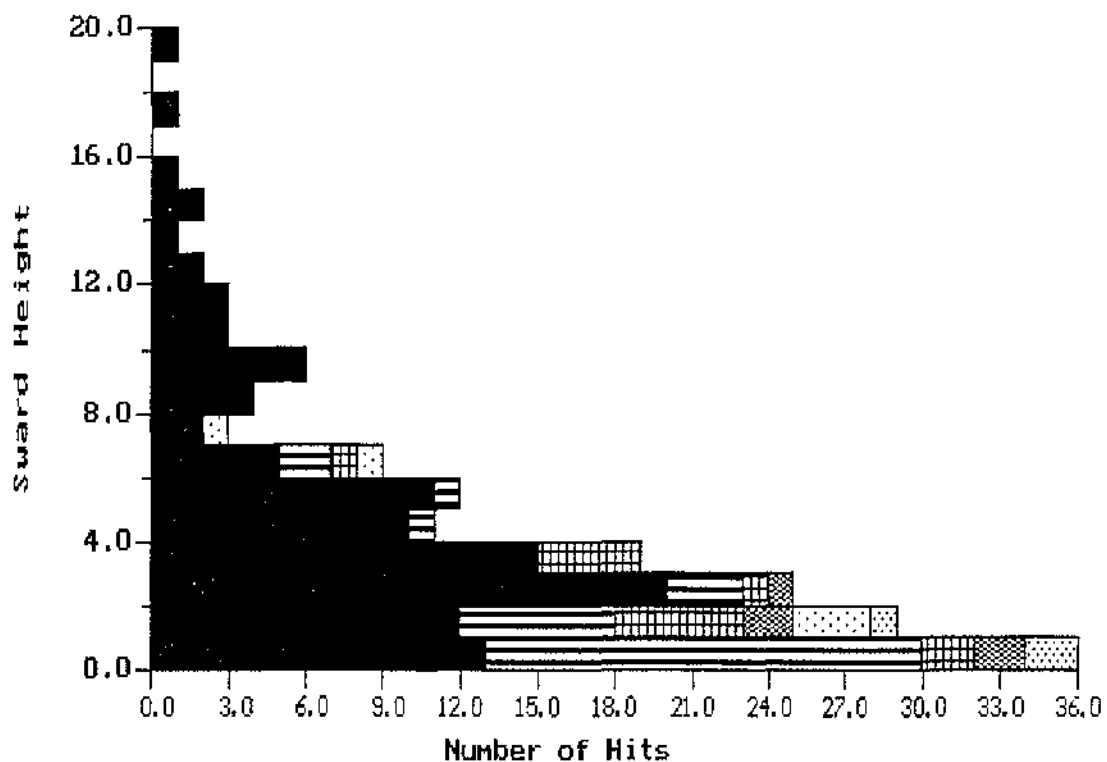
Appendix Figure 1. The proportional distribution of plant morphology for RMB



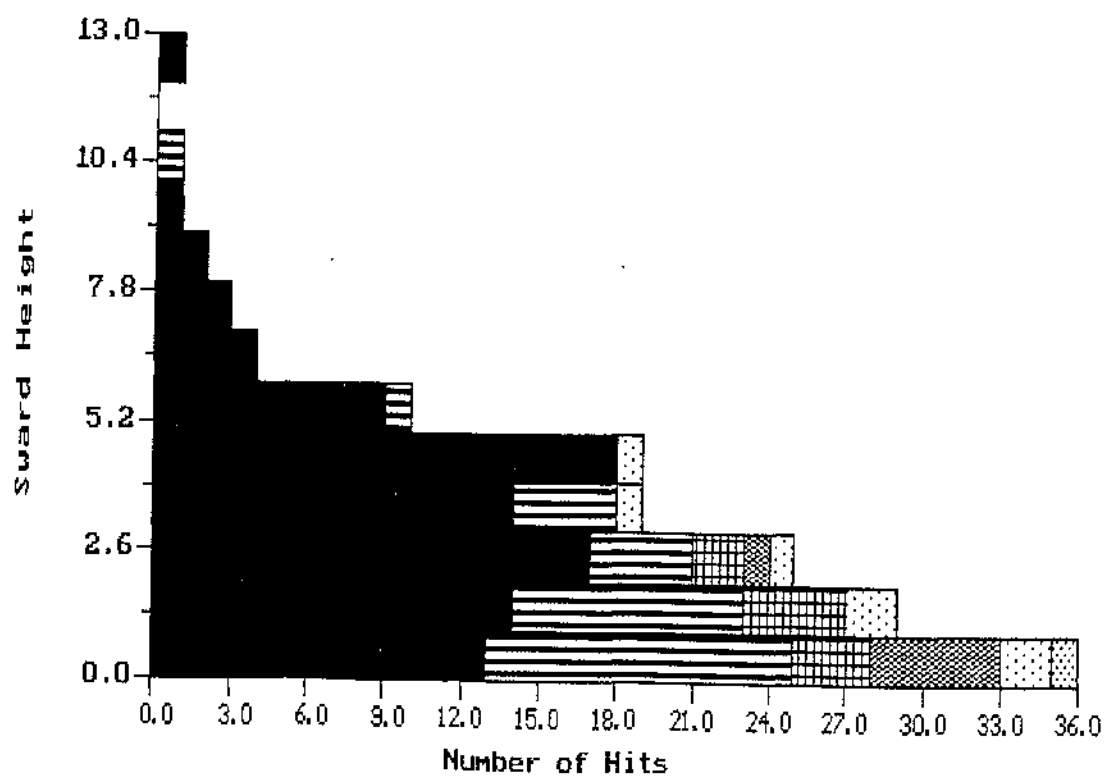
Appendix Figure 2. The proportional distribution of plant morphology for RMA



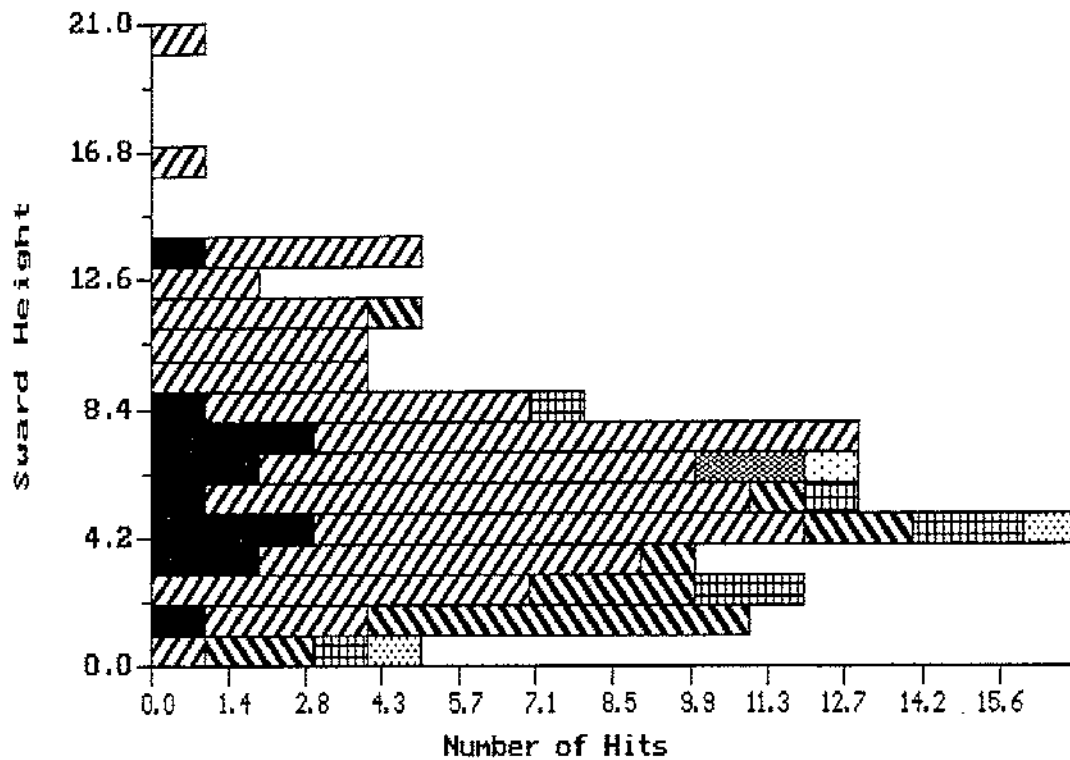
Appendix Figure 3. The proportional distribution of plant morphology for RHB



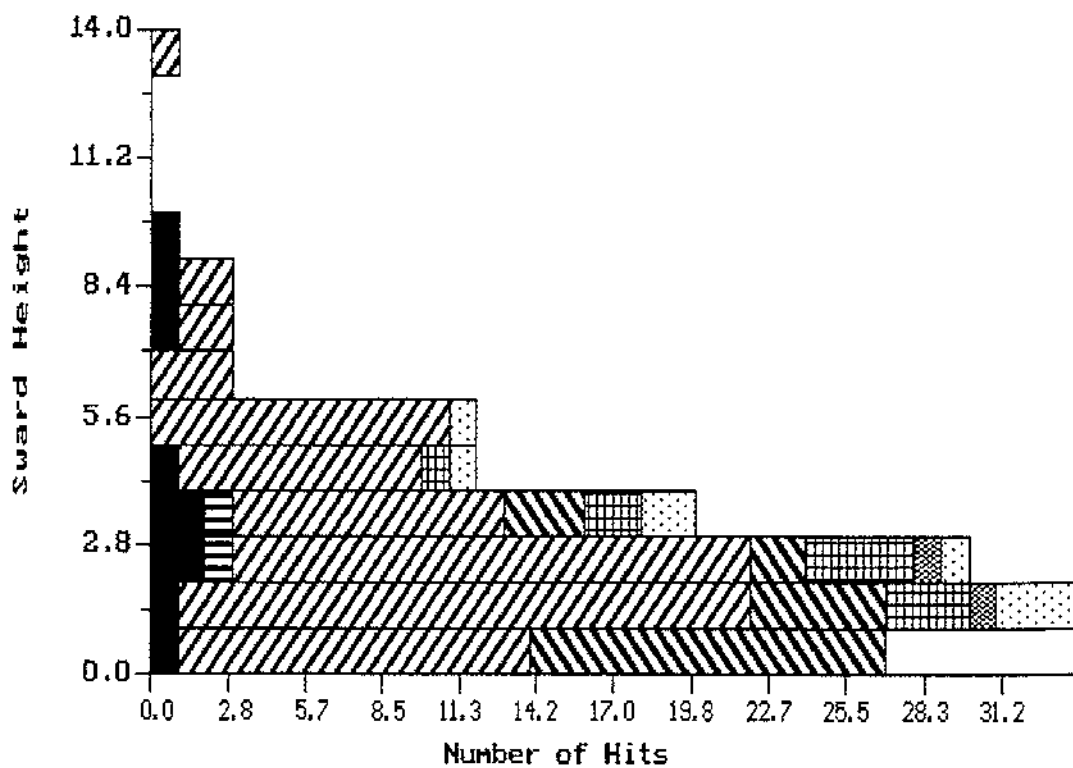
Appendix Figure 4. The proportional distribution of plant morphology for RHA



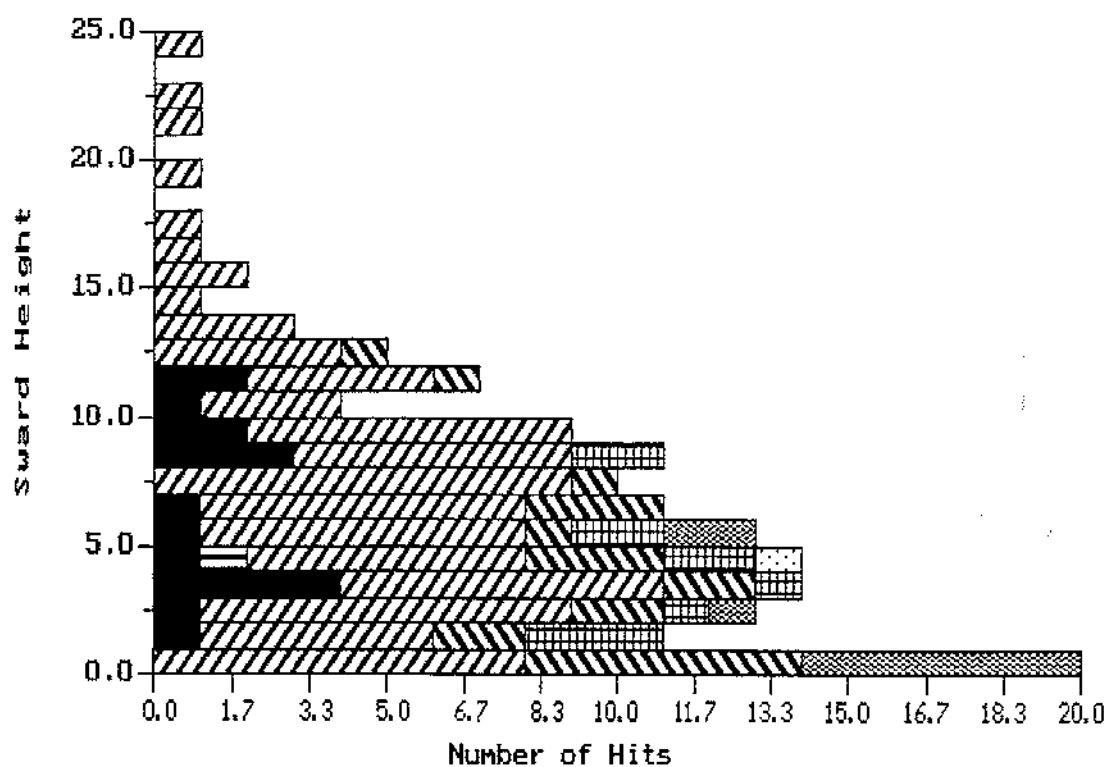
Appendix Figure 5. The proportional distribution of plant morphology for FMB



Appendix Figure 6. The proportional distribution of plant morphology for FMA



Appendix Figure 7. The proportional distribution of plant morphology for FHB



Appendix Figure 8. The proportional distribution of plant morphology for FHA

