SEQUENTIAL GRAZING OF GRASS/WHITE CLOVER SWARDS BY CATTLE, SHEEP AND GOATS.

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To my mother

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ABSTRACT

Two experiments were conducted on sown grass/clover swards (*Lolium perenne - Trifolium repens*) to study the effect of domestic animal species (sheep, goats and cattle) on sward canopy structure and diet selection and animal performance of a subsequent grazing species.

In Experiment 1, the effects of continuous grazing by sheep, goats or cattle at a sward surface height of 6 cm from mid-May to late July (Phase 1) were assessed. From late July until the end of August (Phase 2) swards were continuously grazed at 6 cm by sheep or goats.

Sward composition and structure were measured by a stratified clipping technique taking account of short, medium and tall areas on the basis of their mean sward surface heights and separated into grass and clover morphological components. In Phase 2 the diet selected by oesophageally fistulated goats and sheep was measured. Swards previously grazed by cattle tended to have a higher percentage of clover than those previously grazed by sheep and by goats both in the whole sward and on the sward surface at the end of Phase 1 (sward: 11.8% versus 9.5% and 8.8% respectively; sward surface: 18.2% versus 11.1% and 7.60% respectively). This was particularly related to higher amounts of clover in short and tall areas. During Phase 2 sheep ingested a significantly higher percentage clover from cattle -grazed swards (cattle: 29.7%, sheep: 13.3% and goats: 12.6%; $p<0.001$) whereas the diet of the goats contained 17.3%, 14.0% and 18.9% from cattle, sheep and goats -grazed swards respectively. Furthermore, during Phase 2, there was a greater overall increase in the clover percentage on swards grazed by goats than in those grazed by sheep. Both sheep and goats ingested more clover from

tall areas of the sward with 32.2% and 20.1% of the variation in the percentage of clover in their diets respectively attributed to the percentage of clover present in these areas.

In Experiment 2 ewes and lambs or yearling goats continuously grazed swards maintained at 4 or 8 cm sward height from mid-May to late July (Phase 1). From mid-August to end September (Phase 2) weaned lambs continuously grazed the swards, at 4 cm as in Phase 1 (treatment 4-4 cm), 8 cm as in Phase 1 (treatment 8-8 cm) or at 8 cm following an increase from 4 to 8 cm over 21 days between Phases 1 and 2 (treatment 4-8 cm). Measurements of sward composition and structure were made using similar procedures as in Experiment 1. Also, during Phase 2, measurements of diet selection (using oesophageally fistulated lambs) and herbage intake (using the n-alkane technique) and live-weight gain were made.

By the end of Phase 1 grazing by goats resulted in significantly higher clover percentages than grazing by sheep in the whole sward ($p<0.05$) and on the sward surface ($p<0.001$). Therefore at the beginning of Period 2 there was a higher percentage clover in swards previously grazed by goats than by sheep (37.5% versus 23.8%; $p<0.001$) while percentage clover was also higher on swards allowed to grow from 4 cm to 8 cm than on the other sward height treatments (39.5% versus 26.2% and 26.2% on the 4-8 cm, 4-4 cm and 8-8 cm height treatments respectively; $p<0.001$). During Phase 2 weaned lambs grazing swards previously grazed by goats had a higher percentage clover in their diet (33.1% versus 17.6%; $p<0.001$), higher herbage intake (1.42 versus 1.12 kg DM/day; $p<0.001$) and higher live weight gains (186.7 versus 141.2 g/d; $p<0.001$) than those grazing swards previously grazed by sheep. Sward height treatment also affected animal responses. In Phase 2, weaned lambs

selected a higher percentage clover from the 4-8 cm treatment than from the 8-8 cm and 4-4 cm treatments (37.6% versus 22.2% and 16.2% respectively; $p<0.001$) and this was associated with higher herbage intakes (1.66, 1.19 and 0.97 kg DM/ha respectively; $p<0.001$) and higher lamb live weight gains (206.5 versus 179.8 and 105.6 g/d respectively; $p<0.001$). All of these animal responses were closely related with the percentage of clover present on the sward surface.

It is concluded that cattle and goats may be used in preference to sheep in sequential grazing systems to enhance the contribution of clover in grass/clover swards and to increase the performance of animals such as weaned lambs which may subsequentially graze these swards.

DECLARATION

I hereby declare that this thesis has been composed by myself, and has not been submitted for any other degree, in Edinburgh or elsewhere. I acknowledge all assistance given to me during the designing and execution of the experiments contained in this thesis and during the preparation of this thesis.



Manuel del Pozo Ramos

PUBLICATIONS ARISING FROM THE THESIS

Poster presentation.

del Pozo, M.; Wright, I.A.; Colgrove, P. and Whyte, T.K. (1994). Effect of clover content in the diet on the performance of weaned lambs on grass/clover swards previously grazed by goats or sheep. *Animal Production*, **58**:481-482. Abstract.

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LIST OF ABBREVIATIONS

ANOVA:	analysis of variance
cm:	centimetre
°C:	Degrees centigrade
C_{28}:	octacosane
C_{32}:	dotriacontane
C_{33}:	tritriacontane
C_{36}:	hexatriacontane
DM:	dry matter
ha:	hectare
K:	potassium
kg:	kilogram
K_2O:	potash
LAI:	leaf area index
LW:	live weight
ME:	metabolizable energy
N:	nitrogen
n:	number of observations
ns:	non significant
OM:	organic matter
p:	probability
P:	phosphorus
*:	$p<0.05$,
**:	$p<0.01$
***:	$p<0.001$
P_2O_5:	phosphate
Prsp-C:	cattle pre-species treatment
Prsp-G:	goat pre-species treatment
Prsp-S:	sheep pre-species treatment
r:	correlation coefficient
R^2:	regression coefficient
sed.:	standard error of the difference
Sp-G:	goat species treatment
Sp-S:	sheep species treatment
w/v:	weight by volume

CHAPTER 1

INTRODUCTION

Humankind has historically fostered and relied upon livestock grazing for a substantial portion of its livelihood because it is the principal process capable of converting the energy and protein in grassland vegetation into nutrients directly consumable by humans (Briske and Heitschmidt, 1991). Grazing lands provide essentially all the nutrients for numerous species of large wild herbivores, and the majority of the nutrients for domestic ruminants (Morley, 1981); 71% of the metabolizable energy (ME) and 67% of the crude protein consumed by British ruminant livestock are derived from grazing and conserved grass (Holmes, 1989). The study of the different biological components of grazing systems and their interactions are essential for understanding the gap between the potential and actual performance of grasslands (Pearson and Ison, 1989; Painter, Detling and Steingraeber, 1993).

The range of plants or plant parts eaten is determined by an array of plant, animal and environmental factors but primarily depends on what is on offer and the requirements of the grazer (Gordon and Iason, 1989). The importance of the diet selected and of the level of behavioural regulation of intake by ruminants has been appreciated by many researchers (Allden and Whittaker, 1970; Stobbs, 1973a,b, 1975a,b; Hodgson, 1977; Jamieson and Hodgson, 1979a,b) but detailed knowledge of the animal-sward

interface is still limited.

Furthermore, most of the studies conducted have been of limited value in understanding the influence of sward canopy structure on the ingestive behaviour and herbage intake of herbivores because, in general, pasture characteristics, such as herbage mass, height, density and digestibility, are inseparably associated, confounding the relationships. Also in many studies, the swards have been in a dynamic state, and hence variations in intake are difficult to attribute to pasture characteristics because height and density, as well as nutritive value, undergo change simultaneously. Many of the relationships between sward variables and intake have, therefore, been derived under steady state conditions, for instance on continuous grazing systems, e.g. Hodgson (1981), or short term grazing of carefully manipulated or artificial swards (Black and Kenney, 1984; Burlinson and Hodgson, 1985; Laca, Ungar, Seligman and Demment, 1992a; Laca, Ungar, Seligman, Ramey and Demment, 1992b; McNaughton, 1992; Gross, Hobbs and Wunder, 1993a; Gross, Shipley, Hobbs, Spalinger and Wunder, 1993b). Also, the traditional use of stocking rate (or associated variables such as grazing pressure or herbage allowance) as the experimental treatment does not allow the determination of interpretable input - output relationships because the sward state continually changes over the grazing season (Hodgson, 1985b).

Thus, there is a need to define more closely for each agriculturally important animal species the patterns and ranges of sensitivity in the ingestive behaviour and herbage intake responses in relation to changes in sward variables to manage temperate grasslands efficiently to achieve either agricultural or environmental objectives. Furthermore complementary grazing of populations of ruminant species potentially can produce biologically and

economically more efficient systems. Sown swards of ryegrass/white clover offer a simple model to test hypotheses concerned with the understanding of diet selection and foraging strategy of species such as goats, cattle and sheep with the objective of achieving more efficient use of vegetation resources. Sequential grazing of different species in such grasslands could provide a basis for higher efficiency of pasture utilization in agricultural management systems.

Consequently the main aims of the two experiments discussed in this thesis were:

- to study the effect of animal species (cattle, sheep and goats) grazing at a common sward height on sward canopy structure and on the subsequent diet selected by sheep and goats.

- to measure the effect on diet selection, herbage intake and animal performance of weaned lambs grazing ryegrass/white clover swards previously grazed by sheep or goats at three different sward heights.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction.

The objective of this review is to concentrate on key factors influencing diet selection and herbage intake by sheep, cattle and goats and their impact on grass/clover swards. The review starts with a general description of the sward structure of temperate grass/clover swards (Section 2.2) considering firstly the growth units of perennial ryegrass and white clover plants followed by a discussion of the factors which affect sward dynamics. The effects caused by defoliation are also assessed. In this section special attention is focused on the structure of the sward canopy and on its composition with references to its digestibility and variability in height. That leads to a discussion of diet selection (Section 2.3) and herbage intake (Section 2.4) and how they are affected by sward conditions and animal factors. The importance of the spatial arrangement of the sward components in the canopy is then discussed. Section 2.5 involves a description of management strategies using more than one animal species (sequential and complementary grazing regimes) with a particular interest in identifying the scope for the manipulation of white clover in mixed grass/clover swards. Finally, a short section (2.6) concludes with a summary of the main issues reviewed and identifies the main objectives of the research described in this thesis.

This review does not cover in detail all aspects of animal, sward and environmental factors which define the ingestive behaviour and intake of ruminants in different ecosystems. Only when it is needed to make a particular point or illustrate a principle, are grassland ecosystems other that sown grass/clover swards considered briefly.

2.2. Grass/Clover swards.

2.2.1. Pasture components.

Temperate pastures are a heterogeneous mix of plant species which are principally populations of grasses, legumes and other broadleaved herbaceous plants whose foliage forms a short, dense canopy (Hodgson, 1990). The components vary in chemical composition and proportions of leaf, stem, seed-head, dead and senescing material depending upon the stage of maturity, season and many other factors (Hughes, 1990).

Characteristically, in successful grassland plants, the buds from which growth takes place are situated close to ground level where they are protected from direct damage by defoliation or trampling (Hodgson, 1990). Further, the development of new plant tissue from these growing points is a virtually continuous process so long as climatic conditions allow (Hodgson,1990).

Plant growth is an irreversible, quantitative increase in size, accompanied by changes in plant form, structure

and general state of complexity of the plant (Vallentine, 1990). Growth is localized in meristems capable of cell division and occurs through the subsequent enlargement of the existing cells. The life cycle of a herbage plant is divided into two developmental phases: vegetative and reproductive. A species may be found in more than one developmental pattern according to whether meristems are seen to be producing further leaves or flowers.

2.2.1.1. Grass.

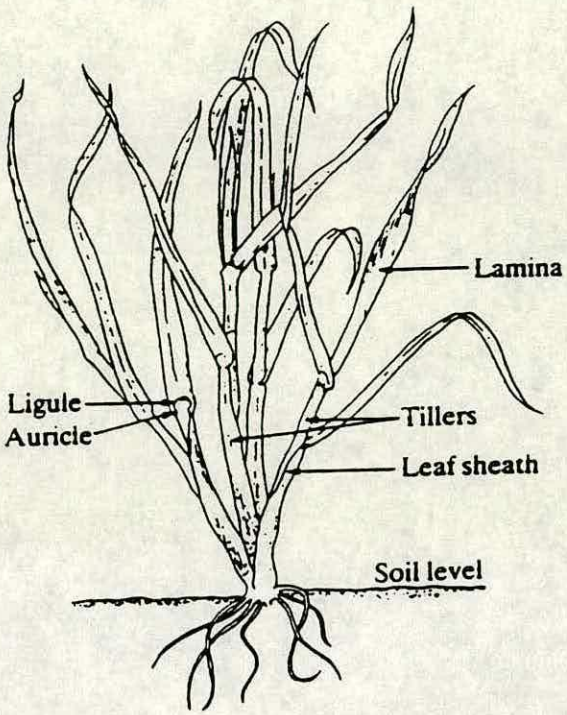
There is a great diversity of species in pastures, but the Gramineae dominate and give their name to the ecosystem: grasslands. From this family, only about 40 are extensively cultivated in pastures (Hubbard, 1984; Leafe, 1988; Holmes, 1989).

2.2.1.1.1. *Morphology*.

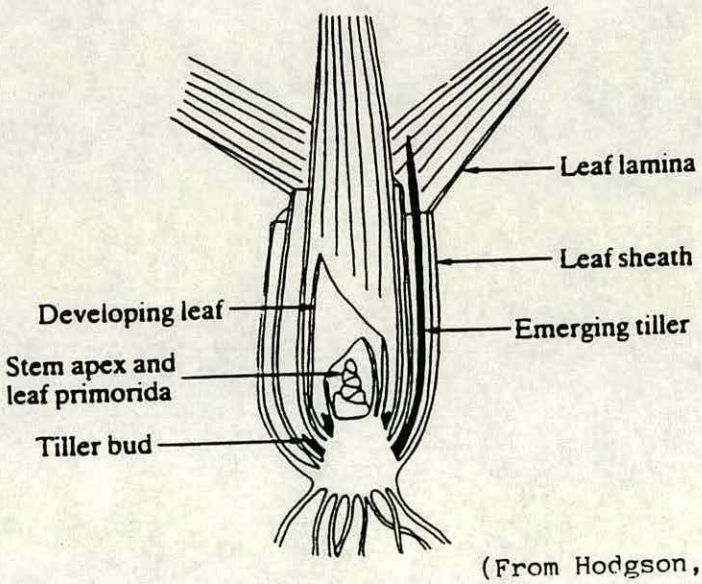
Briske (1986, 1991) defines the *phytomers* as the modular units of growth in grass plants, which consist of a blade, a sheath, an internode, an axillary bud or potential bud and a node (Figure 2.1). Phytomers in graminoids are organized into *tillers* - basic units of production. Hierarchically, tillers are composed of a single growing point (apical meristem), a stem, leaves, roots, nodes (joints) and dormant buds with the potential for producing a seedhead (Langer, 1972; Korte, Chu and Field, 1987; Robson, Parsons and Williams, 1989; Vallentine, 1990).

Figure 2.1. The grass tiller.

(a) Illustration of an established plant of perennial rygrass with four tillers
(b) Stylized cross-section of a vegetative tiller



(a)



(b)

(From Hodgson, 1990)

Variation in tiller architecture among tall, mid- and short grasses does not originate from a major deviation in the pattern of developmental morphology, but rather results from a variable number and/or size of phytomers determining cumulative tiller height (Briske, 1989, 1991). This spatial arrangement of tillers within the grass plant, in addition to morphological variation within individual tillers, is a major determinant of architectural variation within the grass growth form and of the configuration and size of the plant (Robson, Ryle and Woledge, 1988; Briske, 1991).

Branching or tillering shows distinct seasonal patterns, influenced by temperature, radiation and light quality (Thomas and Davies, 1978; Grant, Barthram and Torvell, 1981a; Grant, King, Barthram and Torvell, 1981b; Robson, 1981; Robson *et al.*, 1988; Hunt and Easton, 1989). New tillers appear in an intermittent process which may be brought about by the defoliation of the plant and the consequent improvement in illumination at the base of the sward (Davies, Evans and Esley, 1983; Hodgson, 1990). The rate of growth of new tillers depends on the level of interception of radiation related to plant and sward structure (Arosteguy, Hodgson, Souter and Barthram, 1983; Bircham and Hodgson, 1984; Grant and King, 1984; Treacher, Orr and Parsons, 1986), carbon balance (Thomas and Davies, 1978), environmental conditions (Tallowin, 1981; Grant and King, 1984; Culleton, 1988) and grassland management Culleton and Lemaire, 1985; Curll and Wilkins, 1985; Lantinga, 1986; Treacher *et al.*, 1986; Orr, Parsons, Penning and Treacher, 1988).

Finally, during the reproductive phase, the development of new leaves ceases once stem elongation commences, while the rates of herbage production reach higher levels because of the plant tissue accumulated in

the extended stem, developed flower-stem and expanded seed head (Davies, 1971; Davies and Thomas, 1983; Hodgson, 1990). Parsons and Robson (1982) have related the physiological basis of the superiority of the growth rate of reproductive ryegrass over the growth rate of vegetative swards to the expansion of the reproductive leaves and to their high weight per unit area.

In grass/clover swards in the United Kingdom, the principal sown grass species is usually perennial ryegrass (*Lolium perenne*) although other sown species present may include Italian ryegrass (*Lolium multiflorum*), Cocksfoot (*Dactylis glomerata*), Timothy (*Phleum pratense*) and Tall fescue (*Festuca arundinacea*).

2.2.1.2. White clover.

White clover (*Trifolium repens*) is usually sown in pastures in Northern Europe and has been introduced into North America and New Zealand as a cultivated plant where it contributes around 10-20% of the herbage produced annually (Davies, 1992).

2.2.1.2.1. *Morphology.*

White clover plants develop from seed, with a short primary stem, carrying a rosette with trifoliate leaves and a tap root (Thomas, 1987; Robson *et al.*, 1989; Hay, Newton and Thomas, 1991). The rooted stolon is considered to be the modular unit of growth (Figure 2.2; Korte *et al.*, 1987; Thomas, 1987), although Bircham (1981) defined 'growing point' as an aggregation of two or more petioles associated

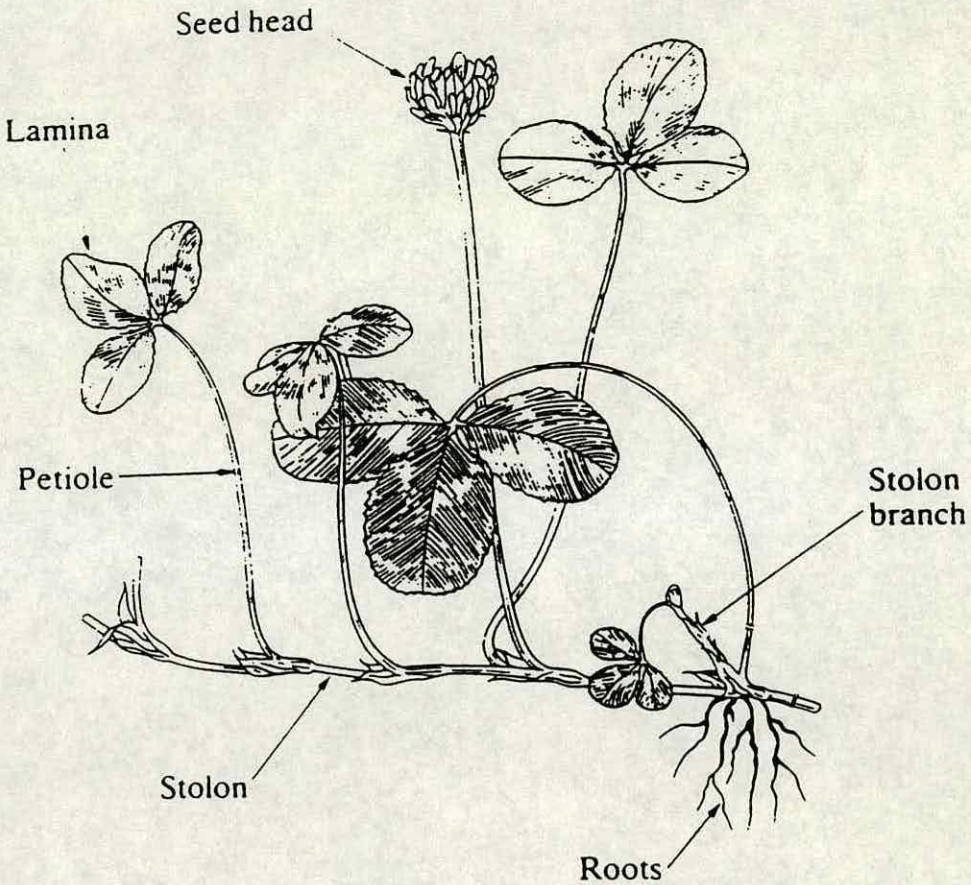
with active stolon formation.

Stolons arise in the axils of leaves on the primary stem, grow close to the soil surface and consist of internodes and nodes, each with a leaf, bud and sometimes roots (Robson *et al.*, 1989). At the tip of the stolon, an apical region produces new leaves, internodes and buds. From buds, daughter stolons, which may branch themselves, can develop on the main stolon (Korte and Harris, 1987; Thomas, 1987). Robson *et al.* (1989) pointed out that the primary stem or tap root normally survives for less than 18 months such that each daughter stolon is then the unit of spread through the sward.

Leaf production (at a rate of one leaf every 3-4 days in favourable conditions) and stolon branching are dependent on temperature (Sackville-Hamilton and Harper, 1989; Sackville-Hamilton, 1990), light (Solangaarachi and Harper, 1987; Thompson and Harper, 1988, Grant, Torvell, Sim and Small, 1991), flower initiation (Brougham, 1962) and also day length, soil water and wind in exposed areas (Frame and Newbould, 1986), whereas differentiation processes and plant size are mainly governed by light factors (Brougham, 1962; Newton, Hay, Thomas and Dick, 1992).

White clover produces a succession of flowers throughout the summer from axillary buds in place of branch stolons when day-length and temperature conditions are favourable.

Figure 2.2. A white clover stolon showing leaf development and stolon branching.



(From Hodgson, 1990)

2.2.1.3. Grass/Clover balance.

When two or more species grow together in a community, they interact with one another (Hodgson, 1990; Langer, 1990; Menchaca and Conolly, 1990) and compete for specific environmental resources that affect growth and development, e.g. water, plant nutrients, light (Langer, 1990). These environmental or abiotic factors are also affected by the sward structure (Turkington, Hamilton and Gliddon, 1991; Thompson, 1993; Tremmel and Bazzaz, 1993) and different management regimes. The importance of these effects and of the interaction between these factors changes according to the different stages of the species' life and with the balance of species composition achieved (Harris, 1987; Robson *et al.*, 1989; Marriott and Grant, 1990).

This competition is conditioned by basic morphological and physiological differences between grasses and clover plants (Marriott and Grant, 1990).

2.2.1.3.1. *Physiological responses.*

White clover has developed characteristics such as (i) rapid attainment of light interception by horizontal leaf arrangement and canopy adjustments arising from changes of petiole length, (ii) the ability to spread widely by stolon growth and explore both the soil and aerial environment, (iii) a different growth periodicity from that of ryegrass and (iv) the used of fixed atmospheric N rather than mineral N from the soil (Harris, 1987).

Ryegrass and white clover have different temperature

responses and different seasonal growth patterns (Davies, 1992). White clover's optimum temperature for growth is around 27 °C (Brougham, Ball and Williams, 1978) whereas ryegrass peaks at 15-20 °C. Also, white clover has a lower rate of growth than ryegrass at temperatures below 15 °C, resulting in white clover starting to grow 2-3 weeks later in spring and to cease earlier in autumn than many perennial ryegrass cultivars used in the United Kingdom. These differences in threshold and optimum temperature for growth of perennial ryegrass and white clover are such that in early spring and autumn, ryegrass is capable of faster growth than white clover while the reverse is the case in summer (Marriot and Grant, 1990; Grant *et al.*, 1991).

With high temperatures or low light intensities, clover produces large and thin, typically 'shade', leaves on elongated petioles (Robson *et al.*, 1989; Barthram, Grant and Elston, 1992). Petiole extension from a meristem positioned below the leaflets depends on the light environment within the sward. Thus, each leaf in turn is positioned in high intensity light close to the top of the canopy by the time its leaflets are unfolded (Dennis and Woledge, 1985). Leaf production is affected by the number of growing points at the beginning of the growth period and the proportion from younger stolons in the total population (Dennis, Woledge, Culhane and Stokes, 1984; Barthram *et al.*, 1992).

Grass leaves are generally erect absorbing the light more evenly throughout the canopy than the horizontal clover leaves. This horizontal arrangement is advantageous when clover petioles are able to extend and maintain their laminae near the sward surface (Hay, 1983; Hay, Chapman, Hay, Pennel, Woods and Fletcher, 1987). However this does not occur in early spring and autumn (Marriott and Grant, 1990) because, at these times, low temperatures inhibit

petiole extension (Marriott and Grant, 1990) and clover leaves occupy a low position within the canopy (Hodgson, 1990).

Once white clover is actively growing, however, its proportion in the sward steadily increases with a higher rate of growth than grass because of differences in specific leaf area and pattern of leaf extension (Parsons, Harvey and Woledge, 1991b).

Application of fertiliser-N to mixed perennial ryegrass-white clover swards generally results in a decrease in the population density of white clover (Frame and Newbould, 1986; Frame and Boyd, 1987; Barthram *et al.*, 1992; Caradus, Pinxterhuis, Hay, Lyons and Hoglund, 1993) because of a reduction in nitrogen-fixing activity of clover (Marriott and Grant, 1990). However moderate spring applications at up 40 kg/ha of nitrogenous fertiliser do not necessarily have this effect (Laidlaw, Teuber and Withers, 1992; Conolly, 1993). The ryegrass population density remains constant when N is applied (Marriott and Grant, 1990), thus affecting the grass/clover balance in a mixed sward (Frame, 1987).

Furthermore, in grass/white clover pastures, white clover is more 'sensitive' to deficiencies of plant nutrients than grass, hence decline in white clover growth and vigour is likely if, for example, soil pH falls, or if soil P or K concentrations decrease substantially (Frame, 1987). Part of this sensitivity is probably due to its lower root mass relative to grass and its root morphology (smaller root hairs and root cylinder).

2.2.1.3.2. *Grazing tolerance.*

Plant species like ryegrass and white clover, do not grow or respond to grazing as isolated individuals, but rather as members of a grassland population (Parsons, Harvey and Johnson, 1991a; Parsons *et al*, 1991b; Harris, 1990). Grazing alters competitive interactions in the balance of grass/legume swards (Grant and Hodgson, 1986). Species like white clover, grazed more severely than less preferred species, are disadvantaged. Moreover, ryegrass and white clover may have different abilities to grow following a period of defoliation because of various tolerance mechanisms (Harris, 1990).

Research has been carried out on grasses in general, and ryegrass in particular, on morphological and physiological tolerance mechanisms which facilitate growth following defoliation. For instance, compensatory photosynthesis rate (Nowak and Caldwell, 1984), reallocation of carbon reserves (Caldwell, Richards, Johnson, Nowak and Dzurec, 1981) and carbohydrate reserves (Richards and Caldwell, 1985), reduction of the transpirational area (McNaughton, 1983), suppression of root growth may change their functional responses (Caldwell, Richards, Manwaring and Eissenstat, 1987), and mechanisms of rapid leaf replacement may develop (Briske, 1991). A detailed description of this research is, however, outside the scope of this review.

In general, defoliation by grazing or cutting suppresses apical dominance and more light reaches the base of the sward. When the frequency and severity of defoliation are increased, a reduction in tiller and leaf angle and in pseudostem length are likely to occur, resulting in a prostrate sward (Hodgson, 1981; Ungar,

Seligman and Demment, 1992). On regrowth the form of the sward, defined by the orientation, shape, thickness and density of the leaves is a major determinant of light interception (Hepp-Kuschel, 1989).

Although the growth rate of the grass depends on these factors, the branching rate of clover stolons may be unaffected because they have the ability to accumulate energy reserves (Davies and Evans, 1990). The capacity to spread horizontally by growth of stolons is an important characteristic for the competitive ability of white clover (Harris, 1987) and allows it to invade unoccupied areas while evading removal during defoliation (Hay, Brock and Fletcher, 1983; Brock, Hay, Thomas and Sedcole, 1988; Hay, Newton and Thomas, 1991; Brink and Pederson, 1993). Taller swards have a greater stolon extension rate (Barthram *et al.*, 1992) resulting in a more rapid invasion of new areas. White clover leaves are normally not severely shaded since successive petioles adjust to the increased height of the sward canopy (Dennis and Woledge, 1982, 1983), although severe grazing by sheep may limit the capacity of white clover for assimilation and colonisation of neighbouring areas (Clark, Rolston, Lambert and Budding, 1984). Briseño de la Hoz and Wilman (1981) observed that white clover plants under sheep grazing responded by reducing the amount of stolon, and the length of the internodes, petioles and leaflets. Stolons were thinner and closer to the ground. When sward height was lowered to 4 cm, white clover dimensions were reduced, compared with 8 cm swards.

Aide (1993) suggests that residual leaf area is the factor which may be the most important in determining vegetative regrowth after defoliation. It is largely a function of the number, source, and location of meristems within a plant following defoliation (Briske, 1991). Furthermore, Gill, Beever and Osbourn (1989), found that

ryegrass tends generally to have higher proportions of leaf and a higher proportion of leaf to stem on regrowth than other temperate grass species.

Grazing management also influences the competitive balance of species by influencing the seasonality or total numbers of new tillers by affecting axillary bud development (Brock and Fletcher, 1993). Species grazed throughout their entire growth period are placed at a competitive disadvantage in the presence of species possessing growth periods which do not coincide entirely with the grazing season. The population of ryegrass tillers in an intermittently defoliated sward usually increases to a peak in the spring, declines rapidly over the flowering season and then remains roughly constant until the following spring (Hodgson, 1990). Removal of a large portion of the photosynthetic surfaces from a grass plant apparently reduces the amount of resources available for tiller growth irrespective of the mechanisms regulating the tillering process e.g. apical dominance, light quality, etc. (Olson and Richards, 1988; Richards, Mueller and Mott, 1988; Busso, Mueller and Richards, 1989; Hodgson, 1990). In contrast, Hodgson (1990) concluded that in continuously stocked ryegrass swards, tiller populations are relatively stable and remain at a higher level throughout the growing period.

In general, in a continuous grazing regime during periods of high pasture availability, high stocking rates and close frequent defoliation favours white clover, while low stocking rates and lax, infrequent defoliation encourages ryegrass. Grant, Barthram, Torvell, King and Smith (1983) showed experimentally that a reduction in space as a result of increased tiller density could restrict clover growing point numbers. In contrast, under intermittent defoliation King, Sim and Grant (1984) found

that the rate of regrowth of ryegrasses under various defoliation treatments increased with higher leaf area index (LAI: the ratio of the leaf surface area of a pasture and the area of the ground on which it is growing). They obtained a maximum weight of herbage harvested between LAI 2 and 3; i.e. regrowth is faster under lax grazing, although the tiller density decreases and senescence increases (Bircham and Hodgson, 1983; Grant *et al.*, 1983; Parsons, Leafe, Collett, Penning and Lewis, 1983). However, Grant and Barthram (1990) showed that the grass/clover balance can be altered by incorporating a period of rest from grazing through enhancing the content of the clover component because of its greater capacity for growth during the rest period.

Finally, within grazing systems, processes such as treading, excretion and defoliation are interdependent factors of different relative importance at various times that can modify the botanical composition of the sward (Forbes, 1982; Curll and Wilkins, 1983; Forbes and Hodgson, 1985b; Frame, 1987; Marriott and Grant, 1990; Barthram *et al.*, 1992; Deenen and Middelkoop, 1992). Excretion of nitrogen either in faeces or urine boosts the ryegrass content of swards (Frame, 1987; Davies, 1988). Applications of N fertiliser in the spring and the summer reduce dramatically the number of clover growing points and increase the amount of dead clover stolons (Grant and Marriott, 1989), creating patchiness of clover in mixed swards. Treading can also cause a reduction in clover content associated with stolon burial (Marriot and Grant, 1990), resulting in changes in species balance especially on wet heavy soils under high grazing pressures (Barthram *et al.*, 1992). These buried stolons are more prone to decomposition (Marriott and Smith, 1992).

Overall, changes in plant species composition alter

the quantity, quality and variability of plant production. Differing responses to defoliation between ryegrass and clover can be attributed to the differential expression of tolerance mechanisms. This section has shown that in mixed swards the growth of clover relative to grass and, therefore, its population density and percentage contribution to the sward can be increased by the imposition of appropriate defoliation regimes, although additional effects of treading and excretal return must also be considered. These responses are also highly influenced by the architecture of the sward canopy: the subject of the next section.

2.2.2. Sward canopy structure.

Since swards consist of a mosaic of leaf and stem distributed vertically as well as horizontally (Forbes, 1982; Davies, 1989), a knowledge of variables such as digestibility, chemical composition and herbage quantity with respect to this structure is important in understanding the process of diet selection and herbage intake within and between plant communities.

The sward canopy concept "carries with it connotations of the distribution and arrangement of the various plant parts" (Hodgson, 1979). A grass sward has therefore not only biomass but a highly organised structure which changes with season and management. Changes in the structure can modify rates of dry matter production, the degree to which the sward is utilized and the feeding value of the herbage (Davies, 1977; Hodgson, 1984; Laca, Distel, Griggs and Demment, 1994a).

The various morphological aspects of sward structure

and their variables (height and digestibility) will be addressed in this section.

2.2.2.1. Vertical arrangement.

Leaf growth takes place principally from the base of a sward and young leaves must penetrate the overlying vegetation before they can reach the light. Hodgson, (1990) described how live leaf is concentrated in the upper layers of the sward, and stem and sheath material in the lower layers. As the young live material overtop older leaves, a developing sward will steadily increase in height if it is not grazed. Dead leaf becomes concentrated close to the soil surface. The density of plant material (mass per unit volume of space occupied), therefore, increases rapidly from the sward surface downwards. Thus, as Hodgson (1990) concluded, a substantial proportion of the total amount of the herbage is concentrated close to the soil surface and in the root zone.

Clover stolons are normally concentrated close to the ground surface but the proportion of clover foliage increases progressively from the lower to the upper layers of the sward canopy because clover leaves are usually arranged in a horizontal plane at the ends of the slender petioles in contrast to the lanceolate leaves of grass plants, many of which are aligned at an angle close to vertical as described by Harris (1987) and Hodgson (1990). Thus, as Robson *et al.* (1989) showed, clover usually has a greater proportion of its leaf area in the upper layers of the canopy than does grass.

As explained above (Section 2.2.1.3.1 and Section 2.2.1.3.2), the location of clover leaves has important

consequences for utilisation and survival. Since young fully expanded clover leaves are photosynthetically efficient and tend to begin their active lives in high light intensity at the top of the canopy (Dennis and Woledge, 1985), in terms of its ability to intercept and utilise light efficiently (Section 2.2.1.3.1), clover would seem more likely to "shade out" grass than the other way around (Robson *et al.*, 1989). This also means, as Hodgson (1990) pointed out, that defoliation at any level within the sward canopy, will have a more serious effect on the clover than on the grass component of the sward.

2.2.2.2. Sward height.

As defined by Bircham (1981) and Hodgson (1981) sward height is a measure of the average height of the lamina above ground level and is related to (i) the leaf area available for trapping sunlight which affects grass growth rate, (ii) the proportion of grass leaves which age and die without being utilised, (iii) the total amount of grass available for grazing and, hence (iv) the amount of grass which can be eaten by the grazer and (v) individual animal performance (Lowman and Swift, 1984). It also reflects plant morphological responses to growth and the defoliation process (Gibb and Ridout, 1986). It thus provides an effective way of summarizing sward conditions, such as variations in leafiness, particularly under continuously stocked swards (Hodgson, 1990) and relates closely to animal responses (Illius, Wood-Gush and Eddison, 1987). Within a defined system of management, sward height and herbage mass tend to vary together (Bircham and Hodgson, 1983; Hodgson, 1990).

2.2.2.3. Digestibility.

Digestibility determines the intrinsic quality of herbage, describing the potential to supply energy to grazing animals.

Quality is a term which encompasses the chemistry and structure of the feed. Influences on the quality of forage are the plant species present and their nutritive value (Morley, 1981; Wheeler and Mochrie, 1981; Van Soest, 1982). There are wide differences in digestibility between plant families, species, their different morphological components within species and particularly due to the physiological state of these components (Armstrong and Milne, 1993). For instance, legumes have less cell walls than grasses, hence contain lower concentrations of both cellulose, hemicellulose and silica, so that they have a higher digestibility value. In general, their presence in the sward will increase the total digestibility of the herbage on offer.

Stems have greater proportions of structural carbohydrates and lignin in all forages, while leaves have greater proportions of cell contents and crude protein than stems. The highest quality is associated with the most metabolically active tissues (live leaves, stems, flowers, etc.) or storage tissue (seeds, fruits and roots), and so a higher proportion of nutrients are available in live plant material than in dead (Van Soest, 1982). Similarly, live leaf is of higher quality than live stem because of its greater photosynthetic activity (Huston and Pinchack, 1991).

Whether the plant is in the vegetative or in the reproductive phase affects the proportion of leaf to stem

in the plant, and has a major effect on its chemical composition (Gill *et al.*, 1989). As the plant matures the proportion of cell contents decrease (the proportion of protein, lipid and mineral matter in the DM decreases) and the proportion of cell wall increases mainly in the stem and inflorescence (Gill *et al.*, 1989). Therefore, concurrent changes in the leaf/stem ratio occur as a plant matures. Environmental conditions in turn can modify quality by affecting the rate at which these processes occur.

From the information above it can be seen that a sward has variation in digestibility not only through its species composition but also through its sward structure. Vegetative tillers of grass carry the youngest leaves near the sward surface and, thus, the top surface horizons of vegetative grass swards usually have a higher digestibility than the lower horizons. However, in contrast, the development of reproductive material results in the formation of an upper horizon of floral parts supported by the flower stems and hence a lower digestibility of the top surface horizons of the sward.

This pattern of distribution of digestibility will also depend upon the way in which the sward has been managed (Hodgson, 1990). In a continuously stocked sward the senescent material is accumulated below the height of defoliation thus depressing herbage digestibility of the lower horizons, but above it most of the herbage consists of fresh, younger leaves and is more digestible (Hodgson, 1977; Grant, Suckling, Smith, Torvell, Forbes and Hodgson, 1985).

In summary, the arrangement of plant components within a sward canopy means that the digestibility of successive layers of herbage within a vegetative sward is likely to

decline with increasing proximity to ground level.

2.3. Diet selection.

What the grazing animal actually ingests is a complex phenomenon determined by the animal, by the plants offered to the animal, and by the environment in which selection occurs. When an animal grazes a plant in the foraging process, a hierarchy of instinctive responses and behavioural actions have been taken by it that leads to the point of prehension and consumption (Crawley, 1983; Senft, Coughenour, Bailey, Tittenhouse, Sala and Swift, 1987; Senft, 1989; McNaughton, 1992).

Each pasture (landscape unit) is composed of a complex of different habitats or distinct groupings of plant species in communities. These habitats are delimited by the type of plant species present, their spatial arrangement, and structural configuration. They can be further delineated into patches which contain more homogeneous groupings of species (Senft *et al.*, 1987; Stuth, 1991; Demment and Laca; 1993). When the animal has oriented itself in a habitat it must decide when to lower its head and establish a feeding station (site selection) along its grazing path. Within the feeding station, the animal must then select from among the individual plant species, those it will consume, and beyond that which of the plant parts will be eaten (Demment, Laca and Greenwood, 1987; Laca, Distel, Griggs, Deo and Demment, 1993). Therefore, the diet selection process has two major levels that must be clearly distinguished, spatial choice (grazing site) and species choice (bite site) as postulated by Hodgson, (1986), Senft *et al.* (1987), Milne, (1991), Demment *et al.*, (1987), Demment and Laca, (1993), Parsons,

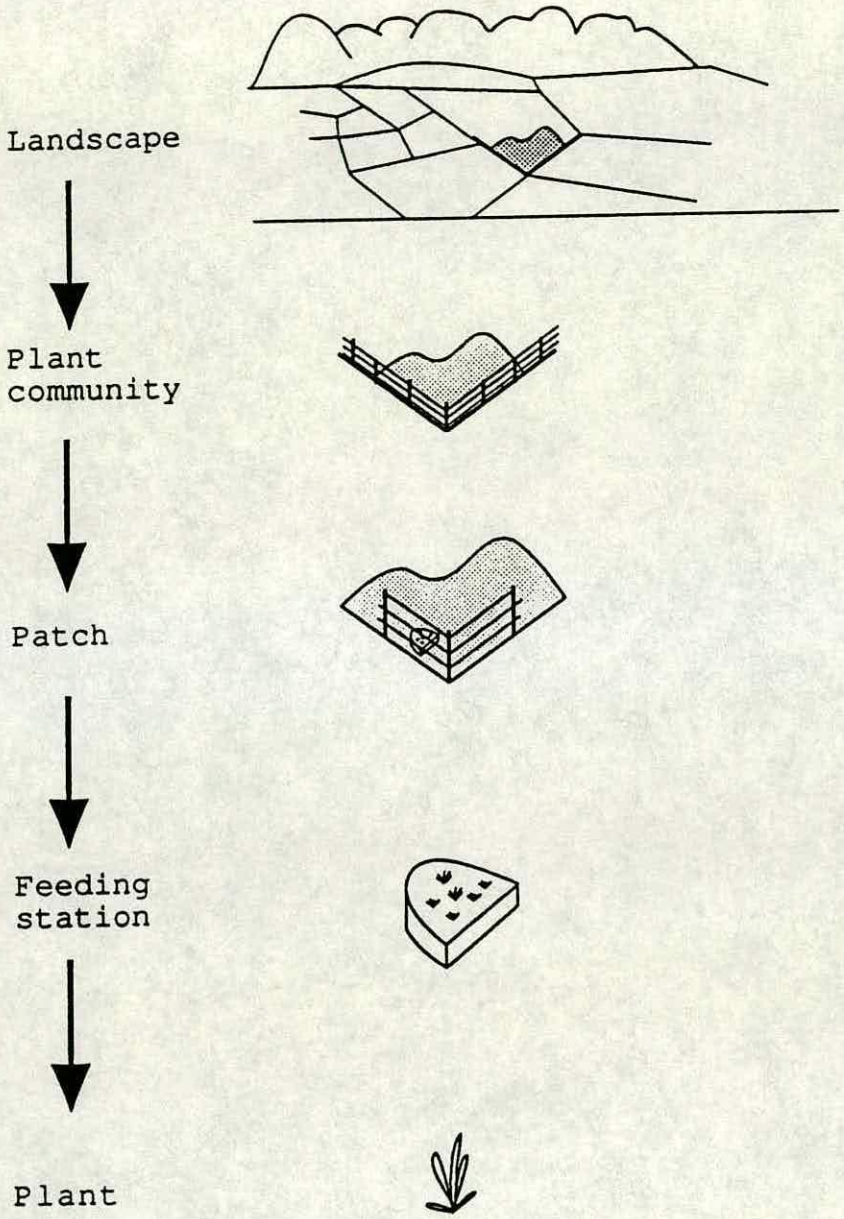
Thornley, Newman and Penning (1994b), and Thornley, Parsons, Newman and Penning (1994)(see Figure 2.3).

Vallentine (1990) and Hodgson (1990) postulated that, given an opportunity of choice, grazing animals are always selective in what they eat choosing or harvesting plant species, individual plants, or plant parts differently from random removal or from the average of what is available. Their diet is usually of higher nutritive value with higher proportions of leaf and live plant tissue and lower proportions of stem and dead tissue than the whole sward (Arnold, 1981; Hodgson, 1986). For instance, limited evidence suggests that sheep and cattle prefer legumes to grasses in mixed-temperate pastures (Clark and Harris, 1985; Clark and Hodgson, 1986; Curll, Wilkins, Snaydon and Shanmugalingam, 1985a,b; Ridout and Robson, 1991; Sollenberger, Moore, Quesenberry and Beede, 1987).

2.3.1. Preference and Selection.

Although palatability and preference are interrelated in their determination of selectivity in grazing, they are different terms (Vallentine, 1990). The term palatability has been restricted to plant characteristics or conditions inherent to a plant species. Preference is the reaction of the animal (essentially behavioural) to these differences (discrimination) exhibited between the components of a sward if all were available without restriction. Selection is defined as the measure of the choice demonstrated in practice (Hodgson, 1990; Vallentine, 1990; Stuth, 1991).

Figure 2.3. An hierarchical view of the diet selection process from the landscape level down to the individual plant.



(From Stuth, 1991)

Palatability refers to that combination of characteristics of the forage that stimulates animals to prefer one forage (or any feedstuff) to another (Heady, 1964). It can be applied collectively to a group of plant species or all plants of a single species or can be restricted to a single part or individual parts of that plant (Vallentine, 1990). Many factors are associated with palatability, including plant chemistry (e.g., concentration of minerals, organic acids or cell wall components) and plant morphological factors such as presence of spines and leaf:stem ratio (Theron and Booysen, 1966; Malechek and Narjisse, 1990).

Preference refers to the selective response made by the animal to plant differences. It is essentially a behavioural response from the grazer to the chemical and physical characteristics of the leaves and stems of particular plant species as they affect the senses of sight, touch, taste and smell (Colebrook, Black, Purser, Collins and Rossiter, 1990a). It presumes both initial opportunity to choose between alternatives and implies an active diet selection by the animal modified by the inevitable limitations to the opportunity for selection which occur in the field (Arnold, 1981; Colebrook, Lynch, Black and Baker, 1990b; Hodgson, 1990; Vallentine, 1990) and ideally is measured by relative intake given free choice (Kenney and Black, 1984).

Consequently, in intensively grazed pastures, the botanical composition of the animal's diet alone is not an accurate index of preference but will depend also on factors such as the relative abundance of the plant species and their morphological components, and their spatial distribution in the sward canopy (Hodgson, 1990; Vallentine, 1990). However, where vegetation is more complex and/or grazing pressure less extreme, animal

preferences may have a more significant influence on plant-animal interactions (Clark, Lambert, Rolston and Dymock, 1982; Lambert and Guerin, 1989). Difficulties are met in comparing the results of selectivity studies because of the many and varied techniques that have been used to measure forage preference (Vallentine, 1990). Preference is always relative to the variety or alternatives offered for selection in these studies. Because palatability of forage plant species is subject to seasonal changes it is difficult to measure this seasonal variation in trials involving singly-offered feeds. Preference, on the other hand, varies between animal species and even between individual animals. Also, because of continual grazing on initially preferred species which decreases availability, the animals may switch to other species (Arnold and Dudzinski, 1978; Vallentine, 1990). This latter effect can be only measured in very closely controlled conditions (Hodgson, 1990).

Broad generalizations about species selection and preference should be tempered by the understanding that animal selectivity is a dynamic, situation-specific process. The use of a selectivity ratio, defined as the proportion of any species, species group or plant part in the diet relative to its proportion in the available herbage provides one means of balancing availability and palatability but only when forage is provided in amounts in excess of inmediate ingestion needs (Vallentine, 1990). Unfortunately, this ratio is correlated with the proportion in the sward and cannot be used in any general model of the grazing process without a knowledge of the spatial variation of grazing responses (Clark, 1987; Newman, Penning, Parsons, Harvey and Orr, 1994). Also, because selectivity ratio rankings will be different for different animal species and even for different groups of the same animal species, depending on past experience and degree of

hunger (Newman *et al.*, 1994), caution is needed in interpreting such indices to explain grazing patterns and to generalize from them.

2.3.2. Plant choice.

In heterogeneous swards, specialised or focused grazing on some plant species may relate largely to their relative preference ranking at the time of active growth (Colebrook, Black and Kenney, 1987). However, the more abundant species may be generally consumed in proportion to their availability and consequently when they are present in high percentages in the sward they might dominate the diet. It can be argued that although these plant species would be not as high in nutrients as the preferred species, they might provide to the animal maximum instantaneous intake rates of energy (Crawley, 1983; O'Reagain, 1993) or a better balanced diet (Westoby, 1974). Further, although the preferred species may usually enhance the diet nutritionally, resulting in better animal performance they may have higher handling time costs (Stuth, 1991). On the other hand, species not readily consumed by animals generally make up a lesser percentage of the diet than the percentage available in the vegetation. Their incidental consumption is believed to be a response to animal sampling of the environment as conditions change (Gordon and Illius, 1988; Stuth, 1991) or by conditioned food preferences (Provenza, Pfister and Cheney, 1992) or to achieve a mixed diet (Parsons, Newmann, Penning, Harvey and Orr, 1994a).

The relationship between consumption of plant species and herbage mass (kg/ha) takes different functional forms. Particular plant species might be preferred regardless of

abundance and the presence of associated species (Skiles, 1984). There are also a group of plants where consumption changes from avoidance to preference as herbage mass declines (Skiles, 1984). These plants exhibit morphological constraints to consumption by animals. Finally, avoided species which are selected in poor correlation with their inherent abundance often contain undesirable nutritional attributes (Skiles, 1984; Stuth, 1991).

In all grazing situations, animals are continually making choices among plants at the feeding station level. This selection is also largely related to the phenological state of the forage (Forbes, 1988b) and to the sward arrangement displayed (Curll and Wilkins, 1982; Milne, Hodgson, Thompson, Souter and Barthram, 1982; L'Huiller, Poppi and Fraser, 1986; Nicol and Collins, 1990) even on apparently homogeneous swards.

2.3.2.1. Sward structural influences on selection.

If we assume that ungulates graze at random within a sward then they will eat a diet similar in composition and quality to that on offer (Gordon and Hutchings, 1993). Animals appear however to seek diets with a higher nutrient density than in the sward as a whole (Provenza and Balph, 1988) although plant and animal constraints may limit their ability to forage optimal.

Hodgson (1986 and 1990) argues that animals will often graze apparently indiscriminately in the surface layers of a sown sward so that the botanical composition of the herbage consumed is very similar to the composition of the

botanical components of the surface horizons. Animals may be reluctant to graze down into sward strata containing pseudo-stem material (Barthram and Grant, 1984). This may be because the structural strength of leaves or stems and therefore the force required for their removal and the number of leaves per bite may increase further down the sward (Black and Kenney, 1984; Burlinson, 1987; Pearson and Ison, 1989; Hughes, 1990; Hughes, Sykes, Poppi and Hodgson, 1991). Research into stiffness, tensile strength and fracture properties of the vegetal components has been conducted in an attempt to relate physical aspects of the diet to selectivity (Hodgson, 1986; Hughes, 1990; Hughes *et al.*, 1991). For instance, Hughes (1990) recorded different tensile strengths of plant components at similar pasture heights on a sown sward.

Therefore, even if clover was not preferentially grazed in a ryegrass-clover mixture, its position in the canopy (with proportionately more of its leaves in the grazed upper horizon of the sward than grass; Section 2.2.2.1) means that the proportion of clover in the diet would be higher relative to the sward content (Curll and Wilkins, 1980, 1982; Milne *et al.*, 1982). Thus, on these relatively homogeneous conditions, Gordon and Iason (1989) and Gordon and Hutchings (1993) postulate that the composition of the diet can be considered as a consequence of a largely unselective grazing habit superimposed on a vertically stratified distribution of plant tissue. However, Milne *et al.* (1982) showed experimentally that even within the grazed horizon of grass/clover swards selection of clover or grass took place depending on its frequency of occurrence in the grazed horizon.

However on tall swards several authors (Clark, 1987; Nicol and Collins, 1990 and L'Huiller *et al.*, 1986) have observed that sheep grazed leaves at the base of the sward

when the surface had predominantly dead material. For example, sheep grazed within 0 to 4 cm from the ground, where 95% of the green leaf was located, even though they had to penetrate the surface canopy where there was abundant dead material up to 20 cm high (L'Huiller, Poppi and Fraser, 1984). This illustrates that provided pasture height is tall enough sheep may graze a horizon other than the uppermost within the sward (Thompson and Poppi, 1990). However Laca *et al.*, (1994a) observed that cattle removed most of the top half of the canopy of hand-constructed swards before biting into the lower horizon. This suggests differences between animal species. Collins (1989) studied the diet selected by oesophageally fistulated cattle, sheep and goats when grazing down sown pasture under a mixed grazing regime. She found that the diet composition of cattle was more similar to that of the entire pasture than to any particular horizon in the pasture, while that of the sheep was the most similar to that of the pasture horizon between 40 and 80 mm above the ground. Diet composition of goats was the most similar to the herbage growing above 80 mm.

Clark and Harris (1985) showed experimentally with strips of plant species that there was an active selection for white clover but no evidence of preference for clover on mixed swards was recorded. However, Illius *et al.* (1992) recorded that when given a choice of sown swards in trays sheep preferred swards with intermediate levels of clover: 40% instead of those with lower or higher levels. Newman, Parsons and Harvey (1992) showed that past experience was important and that sheep, rather than prefer clover, grazed grass when previously grazing clover and vice-versa. This could reflect the needs of the animal to sample uncommon components in the sward to gain information about intake rate and nutritional contents (Illius *et al.* 1992) or the need for consuming a mixed diet (Westoby,

1978; Parsons *et al.*, 1994a).

Sheep appear to graze in parts of the sward where there is a predominance of leaf, irrespective of the plant species and whether the leaf is located at the base or top of the pasture, although Black, Kenney and Colebrook (1987), showed that sheep were unable to discriminate between young vegetative leaf and senescing material when it was below 20 mm on artificially constructed pastures.

Selection for clover, therefore, is not a static phenomenon but may vary with the proportion of clover in the grazed horizon (Clark, Hodgson, Robertson and Barthram, 1985; Clark, 1987; Nicol and Collins, 1990; Hodgson, 1990; Gordon and Illius, 1992; Illius, Clark and Hodgson, 1992; Gordon and Hutchings, 1993) and may be influenced by the vertical distribution of green material (L'Huiller *et al*, 1984).

Therefore pasture height of the preferred components can limit the access of the plant material within a bite catchment (Hodgson, 1985b; Burlinson, Hodgson and Illius, 1991; and Penning, Parsons, Orr and Treacher (1991a) and, as Illius and Gordon (1990) noted, it could constraint the diet eaten by the animal.

2.3.2.2. Spatial choice: Patchiness

In nature, food items tend to be distributed in discrete patches (Clark and Harris, 1985; Illius, 1986; Demment *et al.*, 1987; Demment and Greenwood, 1988; Ungar and Noy-Meir, 1988; Kotliar and Wiens, 1990; Gordon and Lascano, 1993; Laca *et al.*, 1993; Demment, Distel, Griggs, Laca and Deo, 1993; Demment and Laca, 1993; Wiens,

Stenseth, Horne and Ims, 1993). Animals, it is argued, select particular sites and positions within a site for grazing in an attempt to optimize their rate of intake (Kenney, Black and Colebrook, 1984; Stephens and Krebs, 1986). Grazing on temperate swards is, then, strongly related to the distribution and profitability of patches (small areas of intense defoliation). Foraging herbivores may leave a patch offering a declining intake rate because of a reduction in the availability of food (Gordon and Illius, 1992; Demment *et al.*, 1993). The rapid regrowth of new green foliage in a patch previously grazed such that competing vegetation is removed offers the animal a highly desirable food source which in turn may facilitate redefoliation in a relatively large area. This kind of intense patch defoliation and redefoliation is in marked contrast to the more typical selective grazing of individual plants in a mixed plant community (Stuth, 1991). Furthermore, repetitive defoliation may result in the expansion of the size of the patch although in some cases this may lead to the loss of some plant species as noted by Stuth (1991).

Illius (1986) developed a model that included spatial heterogeneity in quality and quantity of forage available to cattle from three patch types on sown pasture. He found that the relative importance of sward height and sward digestibility in determining cattle grazing behaviour is dependent on the ratio of each parameter's values between patches. Stuth and Searcy (1987) characterized the foraging behaviour of cattle at this level into three components, as search time (i.e. time spent travelling between feeding stations), biting rates within feeding stations and duration of biting while at a feeding station. Animals appear to select fewer plant species and focus their selection on plant species which offer the maximum amount of green forage per bite (bite size) within the

primary food group (Dudzinski and Arnold, 1973; Wickstrom, Robbins, Hanley, Spalinger and Parish, 1984; Demment and Laca, 1993; Laca *et al.*, 1993). However, Smith, Rodgers, Dodd and Skinner (1992) argue that in the longer term herbivores may trade off intake rate for diet digestibility and not select the plant species, patch or community which offers the highest instantaneous rate but the highest long term intake rate.

Forage becomes limiting as animals intensify searching to acquire an adequate daily intake until their preferred primary food group is depleted (Arnold, 1987). As the amount of senescent material in the canopy increases, animals reduce search time between feeding stations and increase time at each feeding station (Stuth, 1991). Also, as grazing pressure increases, the number of unexploited feeding stations diminishes (Ruyle and Dwyer, 1985). Searching between feeding stations can occupy 20-30% of the grazing time and appears to be an adjustment mechanism associated with forage quality (Valone and Giraldeau, 1993). Bazely (1990) found that sheep, grazing patches of tall grass of potentially higher nutritive value, increased their patch residence time with taller patches being more intensively grazed than shorter ones when travel times were longer.

Clark, Hodgson, Illius, Hughes and Robertson (unpublished data, cited by Illius and Gordon 1993) offered sheep, cattle and goats patches of perennial ryegrasses covering a range of 9 paired height comparisons while grazing in small plots. Taller patches were preferred by all the species with the goats being the most sensitive and sheep the least to differences in pasture height. Laca, Ungar and Demment (1994b) recorded that steers grazed hand-constructed swards by horizons with greater bite weights on tall sparse swards than on short dense ones of equal

herbage mass.

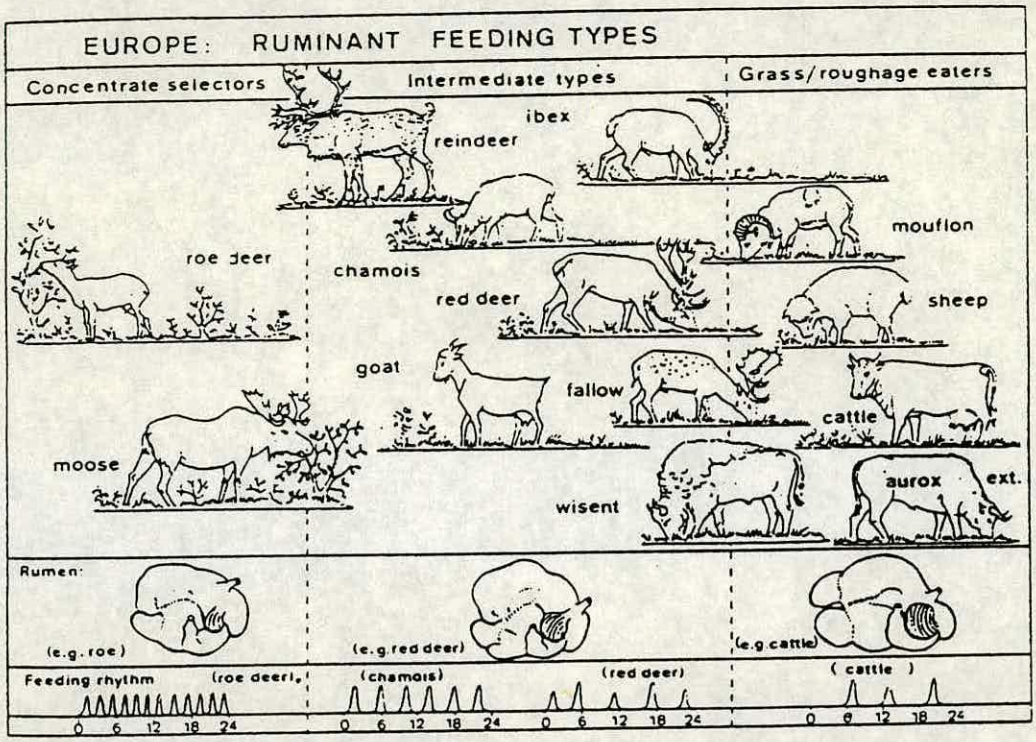
The influence of a single patch can extend well beyond the immediate vicinity and may generate spatially explicit patterns in the sward (Reichman, Benedix and Seastedt, 1993). Gibb (1991) reported a mosaic of short, frequently grazed areas and tall, infrequently grazed areas on swards continually stocked with cattle. There were large within-sward height differences in the vertical distribution of plant parts between the frequently and infrequently grazed areas. Gibb and Ridout (1988) and Gibb and Baker (1989) observed a high percentage of the sward area infrequently grazed by cattle, affecting the balance between grass and clover on these swards.

In sown swards, white clover usually occurs in patches (Clark and Harris, 1985; Illius *et al.*, 1992). Armstrong, Robertson, Lamb, Gordon and Elston (1993) studied the effect of the size of patches and the distance between them on weaned lambs on a mixed grass/clover sward with a constant clover content. They did not find differences in the clover content of the diet of weaned lambs. Conversely, Clark and Harris (1985), Ridout and Robson (1991) and Illius *et al.* (1992) noted selection of the white clover within patches and also between separate areas of grass and clover.

2.3.2.3. Animal factors: Foraging strategies

There are a number of animal variables which determine foraging strategy (Gordon and Iason, 1989). Langer (1984) and Hofmann (1983, 1989) classified herbivores based upon the types of foods eaten (Figure 2.4).

Figure 2.4. Characteristics of European ruminants according to their feeding type; the further to the right, the better a species' adaptation to digest plant cell wall/fibre.



(From Hofmann, 1989)

Hoffmann (1989) argued that species exhibit an evolutionary adaptation, predisposing them to feed on plant species from one or more of their primary groups, grasses, forbs, or browse. Many of these animal variations should be seen as adaptations to a particular diet which have originated across evolutionary time and/or a result of selection imposed by man (Gordon and Iason, 1989). Therefore, the grazing value of a plant will also depend on the animal species constraints in question (Demment and Van Soest, 1981; Hanley, 1982; Hanley and Hanley, 1982; Owen-Smith and Cooper, 1987; Gordon and Iason, 1989; Milne, 1991).

The domesticated ruminant animals, i.e. cattle, sheep and goats, have adopted slightly different foraging strategies along the continuum of grazers, mixed grazers/browsers and browsers with cattle considered as grazers and goats being the nearest species to a browser (Gordon and Iason, 1989; Hofmann, 1989).

Several authors, such as Bell, (1970) Belovsky (1978, 1986), Demment and Van Soest (1985), Gordon and Illius (1989), and Illius and Gordon (1990, 1992, 1993), have considered the implications of the body size of mammalian herbivores for the quality of food ingested by the grazer and hence for the feeding niche selected. Smaller ruminants, like sheep and goats, consume a higher quality diet which necessitates a greater degree of discrimination in diet selection to match the productivity of large ruminants like cattle (Hodgson, 1981; Huston and Pinchak, 1991). The absolute food requirements, the inability for fine-grained food selection and food retention time in the gut all increase with body size (Illius and Gordon, 1987; Gordon and Illius, 1988). Demment and Van Soest (1985) argued that large animals had a greater capacity to process and survive on poor quality forages with slow fermentation rates since energy requirements scale with body weight$^{0.75}$,

and gut contents scale isometrically with body weight. Because of this, in general, the ratio of nutrient concentration per bite required must be maintained at higher levels, for instance, for a goat than for a cow (Poppi, Hughes and L'Huillier, 1987). Retention time of food in the digestive tract was shown by Illius and Gordon (1991) to scale with body weight$^{0.27}$. Also, rumen size relative to body size differs between different species and this is in part responsible for changes in digestive capability for fibrous grasses, trees and shrubs (Demment and Van Soest, 1985; Kay, 1993). For instance, Hofmann (1983) classified the alimentary tract of goats with those from browsers whereas that of sheep was like that of a grazer. Goats tend to be more efficient at digesting low digestibility diets although sheep and goats appear to digest high digestibility forages to a similar extent (Doyle, Egan and Thalen, 1984; Domingue, Dellow and Barry, 1991a; Domingue, Dellow, Wilson and Barry, 1991b). It can be concluded that, in general, there is clear evidence that foraging strategy and digestive ability vary with the species position along the browser-grazer continuum and on the basis of body size.

Significant differences in the morphological structure of mouth parts exist in pre-gastric fermenters and post-gastric fermenters which reflect the types of forages consumed (Grant *et al.*, 1985; Gordon and Illius, 1988; Taylor, Murray and Illius, 1987; Huston and Pinchak, 1991). Animal size is an important determinant of bite weight (Clutton-Brock and Harvey, 1983; Illius and Gordon, 1993). Although Forbes and Hodgson (1985a) found with cattle and sheep that on a live weight basis there was no difference between bite weight either grazing a pasture down or for continuous grazing, on very short pastures Illius and Gordon (1987) showed that bite weight is proportional to incisor width bite and scales as body weight$^{0.36}$ for

ruminants. Size and prehensile agility of the lips, teeth and tongue ultimately determine an animal's ability to consume selectively plant species, individual plants on offer within a species and even discrete plant parts from a heterogeneous assemblage of plant biomass on a temperate sward. In general, increased pliability of the lips and manipulative capacity of the tongue denote greater levels of selectivity from the surrounding material (Gordon and Illius, 1988).

Cattle, considered to be bulk/roughage grazers with a wide and flat muzzle, are thus incapable of exerting similar selective behaviour to sheep and goats because of their mouth size and prehensive behaviour. They graze comparatively indiscriminately on the herbaceous fraction of vegetation by wrapping their tongue around individual clumps of plant material and with a short jerking motion of the head, breaking the clump loose then drawing it into their mouths (Forbes, 1982; Phillips, 1993) although Albright (1993) demonstrated that the sense of taste in dairy cattle is highly developed and can influence their preferences.

The domestic sheep is classified as an intermediate feeder, but its diet often approximates to that of the bulk/roughage group. Their smaller bite size and lips, which can move away from the teeth, allow them to graze closer to the ground than cattle and hence they can harvest many prostrate plants (Dudzinski and Arnold, 1973; Lynch, Hinch and Adams, 1992). Sheep are thus often grazed after cattle have been removed to obtain greater utilization of available herbage (Lynch *et al.*, 1992). When grasses are prehended, sheep move the head posteriorly with a sudden jerking movement while when eating shrubs they can either strip the branch of leaves or break the twig and chew it (Lynch *et al.*, 1992). Their relative narrow muzzle allows

them to select plant parts with a greater precision than cattle.

The goat is a true intermediate feeder (McCammon-Feldman, Van Soest, Horvath and McDowell, 1981), being very flexible and opportunist, with its diet selection clearly overlapping the entire array of forages (Morand-Fehr, 1981; Devendra and Coop, 1982; Devendra and Burns, 1983; Malechek and Provenza, 1983; Mason, 1984; McGregor, 1985; Lu, 1988; Russel and Mowlem, 1988; Ricardi and Shimada, 1992). Goats show a great avidity to graze woody species and can be used to control rushes, gorse and other weed species in pasture (Harrington, 1978, 1982; Huston, 1981; Lambert, Clark and Rolston, 1981; Malechek and Provenza, 1981; Merrill and Taylor, 1981; Somlo, Campbell and Pelliza-Sbriller, 1981; Schwartz and Said, 1981; Russel, Maxwell, Bolton, Currie and White, 1983; Grant, Bolton and Russel, 1984; Provenza and Malechek, 1984; Radcliffe, 1985, 1986; Betteridge and Lambert, 1985; Russel, Lippert, Ryder and Grant, 1985; McCall and Lambert, 1987; Russel and Lippert, 1987; Howe, Barry and Popay, 1988; Clark and Lambert, 1989; Mellado, Foote, Rodriguez and Zarate, 1991; Narjisse, 1991; Owens, 1991; Ramirez, Loyo and Mora, 1991; Papachristou and Nastis, 1993a,b).

Their narrower and more pointed dental arcade than sheep and cattle, typical of browsers, implies a higher degree of selectivity of surrounding material of lower quality (Gordon and Illius, 1988). Goats showed differences in diet selection from sheep on rangelands (Clark *et al.*, 1982; Lu, 1988; Norton, Kennedy and Hales, 1990), consuming more grass and forb species when available and more browse during the dry season or winter when grass and forbs are limited (Ramirez, Rodriguez, Flores, Carlos and Garcia, 1990; Schacht and Malechek, 1990; Gordon and Illius, 1992).

Stuth (1991) showed on studies with Cashmere goats grazing cool-season, grass-legume pastures without browsing material present, that they consume mostly grasses, with legumes comprising less than 10% of their diet. In contrast to sheep, goats apparently select against legumes in temperate grasslands (Lambert *et al.*, 1981; Clark *et al.*, 1982; Clark *et al.*, 1984; McGregor, 1984; Clark, 1987; Russel and Lippert, 1987; Radcliffe and Francis, 1988), although Hughes, Sykes and Poppi (1984) failed to show marked differences between lambs and kids and Nicol and Collins (1990) found that selection against white clover did not exist when it was a part of the goat's grazing horizon. Furthermore, Penning *et al.*, (1993b) and Stevens, Casey, Lucas, Baxter and Miller (1992) recorded that goats' diets contained white clover and red clover respectively while Norton *et al.* (1990) showed goats to have a higher proportion of legumes in their diet than sheep on tropical swards. Also, in a series of mixed grazing experiments Collins (1989) found that clover was present in greater proportions in oesophageally fistulated samples from cattle, sheep and goats than from the pasture being grazed (by +7.9%, +41.7% and +24.1% on cattle, sheep and goat samples respectively). Clark (1987), Collins and Nicol (1987), Nicol (1988) and Norton *et al.* (1990) explained these differences as arising from the interaction between the feeding style of goats and sheep and the vertical position of legumes in the sward canopy in temperate as compared to tropical grassland. Thus the apparent discrimination by goats against clover in temperate grass/clover swards may simply be due to their feeding behaviour rather than active discrimination. Nevertheless, this may offer scope for the complementary grazing of goats and other grazing species. Also, goats and sheep can afford to select smaller plants or plant parts that are less profitable for cattle; to a goat a browse leaf

presents a proportionally larger bite size than to a cow (McCall and Lambert, 1987). This also suggests scope for complementary grazing.

According to Arnold (1981), the animal's physiological state does not appear to affect its dietary preferences although Arnold, McManus, Bush and Ball (1964), and Newman *et al.* (1994) suggested that hunger could alter the composition of the diet of the sheep.

Breed and age may influence the diet ingested. Zoby and Holmes (1983) suggested that younger cattle grazed more selectively but Hodgson and Jamieson (1981) did not find differences in dietary discrimination between cattle of different ages although later Hodgson (1982a,b) mentioned unexplained variation in diet selection between animals of differing age within a species. Hughes, Sykes and Poppi, (1984) indicated that on similar swards older goats consumed a diet similar in composition to young goats while older sheep consumed more dead material than lambs although the differences concerned were small. The *in vitro* digestibility of the diet selected was also not affected. Conversely, Arnold (1970), Curll and Davidson (1983), Provenza and Malachek (1986), Flores, Provenza and Balph (1989a,b) and Nolte, Provenza and Balph (1990) demonstrated that experience, which may be related to age, may be important in influencing the foraging behaviour of sheep, cattle and goats. Newman *et al.* (1992) related the preference of clover by sheep to previous experience.

The recognition of parasitism as a potential factor influencing diet choice suggests new areas for future research (Lozano, 1991). For instance, Taylor (1954) suggested on sown swards that sheep and, particularly lambs, because of their preference for clover leaves might ingest most of the nematode larvae carried on the

trifoliate leaf of the white clover while the upper leaves of grasses are relatively free. Lozano (1991) postulated that parasites could influence diet choice in three ways: (i) potential hosts could avoid some food items that commonly are sources of parasites (ii) by selectively eating certain food items, an animal could alter its internal environment and make it less hospitable to parasites and (iii) certain foods could be selected because of specific antiparasitic compounds that might cause the expulsion of parasites already established.

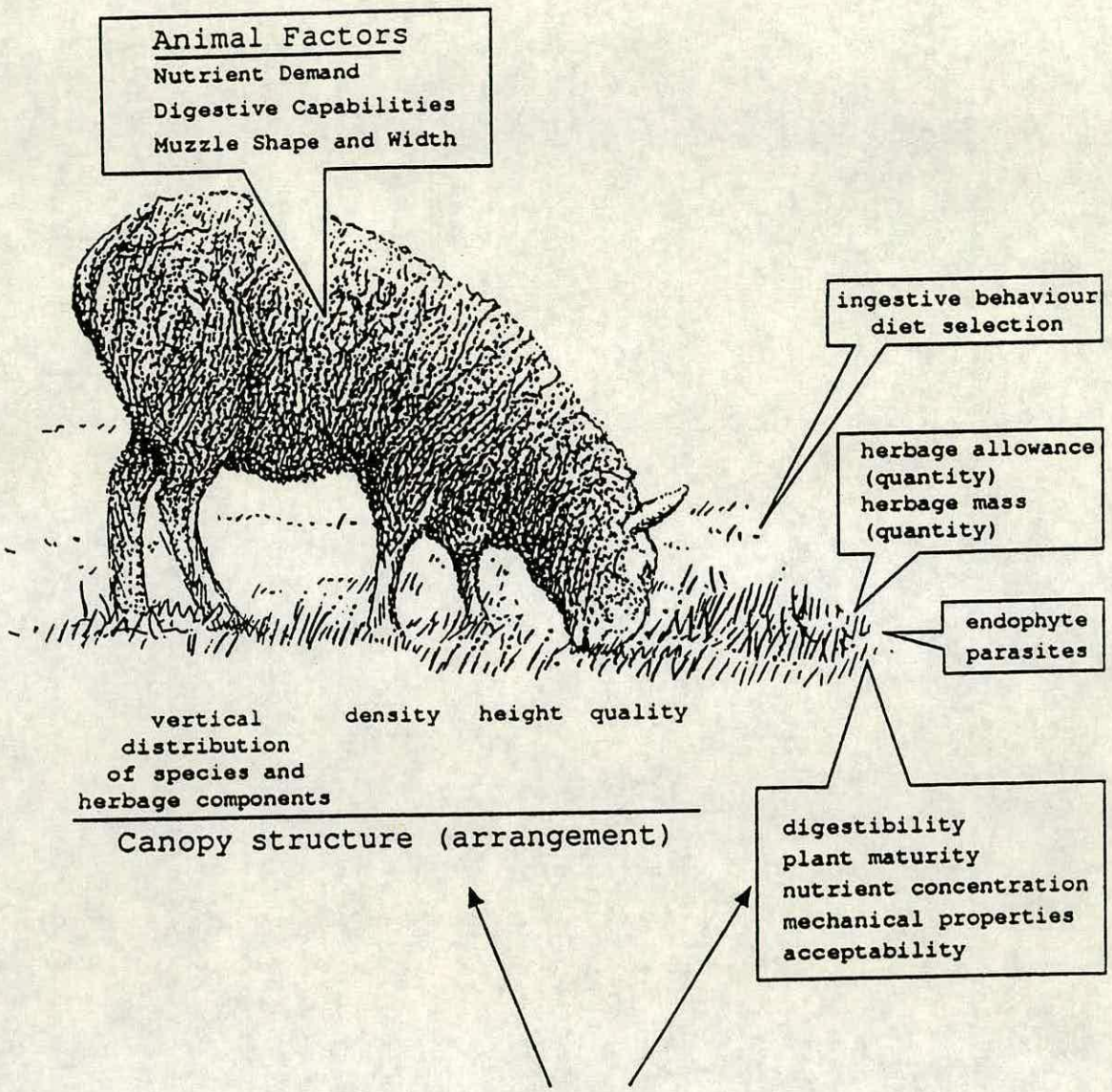
Finally, the concept of "nutritional wisdom" of herbivores implies a primary foraging objective of minimizing the ingestion of many secondary compounds (Westoby, 1974; Gordon and Illius, 1992). Goats seem to be able to digest forages containing secondary compounds more extensively than sheep (Howe *et al.*, 1988). The role of such secondary compounds in plants in terms of their potentially multifaceted role in influencing diet selection is currently being actively studied (Barry and Blaney, 1987; Provenza, Nolan and Lynch, 1993). Taste aversion has been studied in the majority of studies on dietary learning in ruminants as the key factor in the sampling process (Colebrook, Black and Kenny, 1985; Flores *et al.*, 1989a,b; Provenza and Balph, 1990; Zahorik, Houpt and Swartzman-Andert, 1990) and could be more important than sight, smell or touch in influencing bite selection (Milne, 1991). Illius and Gordon (1990) proposed that herbivores can take up to 40,000 bites in a day to gain information and this may reflect the requirement of the animal to sample uncommon components in the sward in order to gain information (Newman *et al.*, 1992). However, there is little evidence that herbivores can sense the amount of nutrients ingested from the pasture (Arnold, 1981).

2.4. Herbage intake.

Forbes (1988b) theorised that intake is controlled by the energy balance of the animal in the long term while in the short term it is probably controlled by a combination of plant structural factors that influence rate of ingestion, the effect of the masticated forage on gut fill, and by social behaviour and environmental factors affecting the appetite-satiety complex. In the first case, regulation of intake is dependent only on endogenous mechanisms triggered either within the animal or by some characteristics of the forage (Forbes, 1980; Van Soest, 1982; Grovum, 1986), while forage (nutrient) intake under grazing conditions is a modified expression of voluntary intake and is influenced by forage quality, forage availability, sward structure, environmental stress, and management (Chacon and Stobbs, 1976; Hodgson, 1977; Arnold and Dudzinski, 1978; Allison, 1985; Young, 1986)(Figure 2.5).

This part of the review concentrates on the intake of pasture by grazing animals as determined by the opportunity to harvest forage. The needs of the animal, the quality of the pasture and the ease with which herbage can be collected all affect the quantity of herbage consumed (Cordova, Wallace and Pieper, 1978; Hogan, Kenney and Weston, 1985; Wilson and Harrington, 1984; Allison, 1985; Hodgson, 1985a,b; Birrell, 1989; Holmes, 1989; Black, 1990; Gudmundsson, 1991).

Figure 2.5. Factors influencing pasture intake in grazing animals.



(From Hughes, 1990)

Classical work on functional responses (Noy-Meir, 1975; Hodgson, 1977; Crawley, 1983; Penning, 1986; Poppi *et al.*, 1987) indicated that when pasture is offered to an animal in increasing quantity (increasing pasture allowance, pasture mass or pasture height) intake increases curvilinearly (Figure 2.6). There are two quite distinct sections of this curve. Daily intake is limited by harvesting or prehension constraints and/or animals' grazing strategies as modified by pasture structure (McClymont, 1967; Allden and Whittaker, 1970) in the ascending portion of the curve when feed is limited. At the plateau or asymptotic section of the curve, nutritional factors, such as physical, metabolic and digestibility constraints, appear to influence the maximum level of intake and hence the production potential (Poppi *et al.*, 1987; Forbes, 1988a; Black, 1990). This general response changes with pasture species. Chacon and Stobbs (1976) reported experimental evidence of this distinction between nutritional and non-nutritional factors. Steers on a high stocking rate (low pasture allowance) did not have a full rumen and did not increase grazing time markedly if digesta was physically removed from the rumen while those animals on a low stocking rate increased their grazing activity.

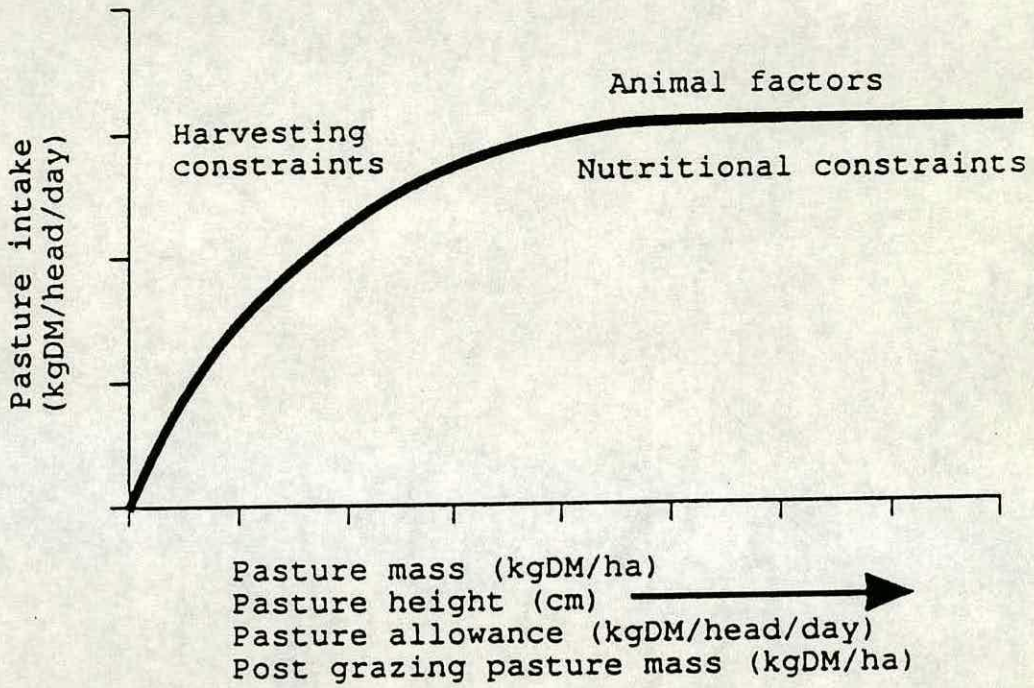
In grazing dairy cattle Hancock (1952) proposed a mechanistic explanation of the amount of herbage eaten daily as

daily pasture intake = rate of intake x grazing time

rate of intake = intake per bite x rate of biting

When intake per bite is reduced there will be a corresponding decline in the rate of intake unless there is a compensatory increase in the rate of biting (Penning, 1986; Hodgson, 1990).

Figure 2.6. The relationship of pasture intake to various pasture characteristics and methods of pasture allocation.



(From Hughes, 1990)

Daily intake will be adversely affected unless any reduction in rate of intake can be offset by an increase in grazing time. Hodgson (1990) argued that, in practice, although either biting rate or grazing time tend to increase when intake per bite decreases, these changes are seldom large enough to prevent a fall in daily herbage intake.

2.4.1. Components of ingestive behaviour.

2.4.1.1. Intake per bite.

Intake per bite is a function of the physical characteristics of the animal and of the plant material on offer (Demment *et al.*, 1987; Forbes, 1988b; Spalinger and Hobbs, 1992). Burlinson *et al.*, (1991) defined the bite dimensions as bite depth, bite area and its product, bite volume: the volume occupied in the sward by the herbage prehended in a bite. All of these interact with the distribution of biomass per unit area (bulk density) of the sward to produce the intake per bite.

Intake per bite is a function of what the animal selects, and a number of studies with cattle and sheep show that the order of preference is leaf, stem and then dead material (Forbes, 1982). Black and Kenney (1984), Hodgson (1986) and Kenney and Black (1986) argued that intake per bite in vegetative swards also appear to be influenced by the depth of the layer within the sward canopy containing mainly leaf material, since this influences bite depth and, hence, bite volume.

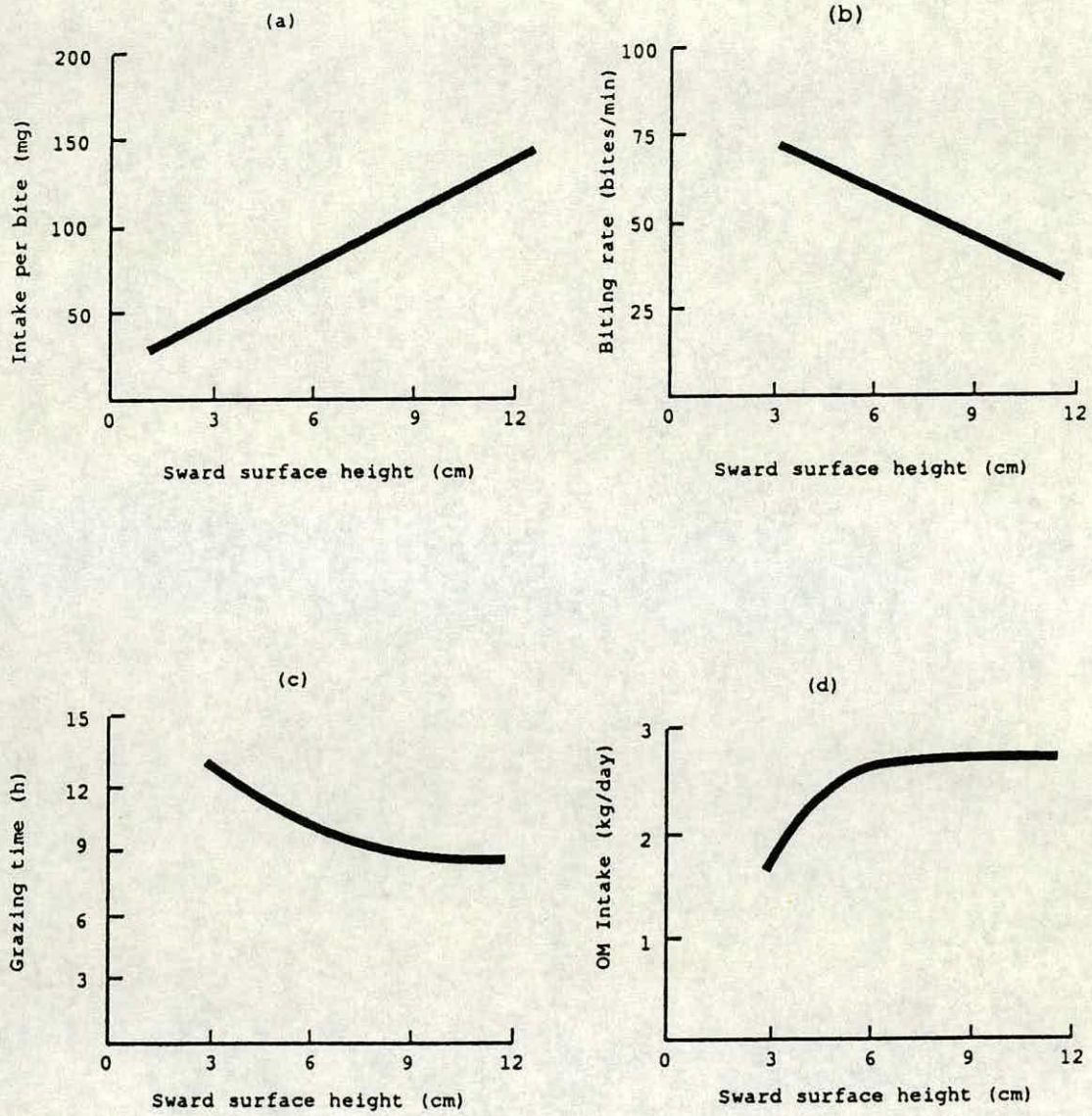
Layers containing leaf sheath appear to limit the

depth of the grazed layer. Burlison (1987) found that sheep frequently penetrated to about half of the depth of the leafy zone of the sown swards. Bite depth is mainly determined by pasture height (Ungar, Seligman and Demment, 1991) but Barthram (1981) with sheep and Arias, Dougherty, Bradley, Cornelius and Lauriault (1990) and Ganskopp, Angell and Rose (1994) with cattle, showed that mean grazed height may not provide a good index of intake limitations unless they can be related to information about the distribution of pseudostem within the sward canopy which appears to reduce the herbage intake of both sheep and cattle. However, Flores, Laca, Griggs and Demment (1993) with steers did not find that the pseudostems of microswards of *Dallisgrass* were a barrier to defoliation although they confirmed the importance of the stem horizons and their relative positions in the sward as determinants of intake per bite. Milne (1991) concluded that within a species bite depth is a more important determinant of bite volume than bite area. The bite depth may determine whether components at various levels in the canopy are available for consumption. With sheep grazing ryegrass pastures, intake per bite appears to be linearly related to sward height, at least up to a height of 12 cm (Penning, 1986; Figure 2.7a).

2.4.1.2. Biting rate.

Biting rate is the number of prehending bites per unit time. It usually tends to decline as sward height or herbage mass increases and as intake per bite increases, principally because the ratio of manipulation to biting jaw movements increases as intake per bite and the size of individual plant components prehended increase (Jamieson and Hodgson, 1979a,b; Hodgson, 1986; Penning, 1986).

Figure 2.7. The influence of pasture height on the components of ingestive behaviour in sheep.



(From Penning, 1986)

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The rate of jaw movements (biting plus manipulation) during grazing across a range of sward conditions were between 22-97 bites per minute in sheep (Black and Kenny, 1984; Penning, 1986) while a different range of bite rates (20-66 bites per minute has been quoted for cattle (Forbes, 1982). These variations in bite rate are better thought of as a direct response to variations in sward conditions rather than as an attempt by the animal to compensate for reduction in intake per bite (Hodgson, 1986). Reciprocal changes in intake per bite and bite rate may balance to maintain a roughly constant rate of intake on relatively tall swards, but on shorter swards any increase in biting rate is inadequate to balance the decline in intake per bite and rate of intake declines (Hodgson, 1986; Figure 2.7b).

2.4.1.3. Grazing time.

Gordon and Hutchings (1993) indicated that little progress had been made in identifying and measuring the factors affecting the time grazing animals spend foraging compared to those affecting bite weight and bite rate. On temperate swards it is generally assumed that grazing time increases as herbage mass or sward height decreases (Penning, 1986; Figure 2.7c) with maximum grazing time constrained by the necessity to conduct other behaviours (Penning *et al.* 1991a). Penning, Rook and Orr (1991b) showed experimentally that sheep grazing white clover spent a shorter time ruminating and grazing with shorter meals than did sheep grazing grass swards although the inter-meal interval was the same. Also they found a certain degree of diurnal control of grazing activity because about 70-90% of the grazing activity occurred during the daylight hours, with nearly 40% of this activity concentrated during the

4 hours prior to sunset. Finally, Hodgson (1990) suggested that a grazing time in excess of 8-9 hours/day is likely to be indicative of limiting sward conditions.

Consequently, Penning, Parsons, Newman, Orr and Harvey (1993a) questioned the value of short-term intake studies using individually penned animals (e.g. Black and Kenney, 1984; Illius *et al.*, 1992; Newman *et al.*, 1992) because these experiments last at the most for 1 or 2 minutes and cannot therefore deal with the mechanisms controlling grazing time.

2.4.2. Effect of pasture characteristics on intake and performance.

Having dealt above with the components of ingestive behaviour this section will now explain how these factors interact with sward conditions to determine intake and performance of different animal species. Pasture characteristics cause variations in intake through several factors such as availability of the feed, pasture species composition and quality of the pasture and sward structure (Sibanda, 1984; Penning, Parsons, Hooper and Orr, 1989; Albright, 1993).

Historically the relationships between forage availability and intake have been described in relation to forage standing crop (Jamieson and Hodgson, 1979a), and to achieve adequate experimental control over these factors (pasture height and bulk density) many of the relationships between sward variables and intake have therefore been derived under steady state conditions (continuous grazing e.g. Hodgson, 1982b), or short term grazing of carefully manipulated or artificial swards using 'sward boards'

(Black and Kenney, 1984; Laca *et al.*, 1992a,b; Flores *et al*, 1993; Gross, Hobbs and Wunder, 1993a; Gross, Shipley, Hobbs, Spalinger and Wunder, 1993b), grazing cages (Burlinson and Hodgson, 1985; Burlinson, 1987), turves (Hughes, 1990; Illius and Gordon, 1990; Newman et al., 1992) and monoculture fields (Penning, Parsons, Harvey and Orr, 1993b) or strip swards (Clark and Harris, 1985; Ridout and Robson, 1991).

Pasture species influence the intake response curve. With legume pastures animals reach their maximum intake at a lower level of pasture allowance than with grass pastures because of the differing structure of the plant species which influences the ease of eating (Hodgson, Clark and Wewala, 1989). Also, animals grazing legume pastures have a higher plateau (maximum) dry matter intake than those grazing grass pastures (Poppi *et al.*, 1987).

Pasture quality influences the response curve by determining the maximum intake (plateau value) possible from a pasture species (Poppi *et al.*, 1987). Herbage intake has long been recognized as being positively correlated with the digestibility of the forage up to a value of 0.80 (Hodgson, 1977). The relationship between intake and digestibility is not consistent for all pasture species with intake of legume being up to 40% greater than grass and leaf 100% greater than stem when compared at the same digestibility (Ulyatt, 1981). Also, variations in digestibility between anatomical plant parts (ranging from 0.40 for dead material to 0.85 for grass or legume leaf) will affect the quality of pasture ingested. Thus sward composition may influence intake through differences in digestibility (Thompson and Poppi, 1990). Grazing conditions are more complex because of variation with time in availability, physical structure of the forage and environmental conditions (Hodgson, 1986). In sown pasture,

pasture digestibility is generally high and digestibility of the diet selected does not differ markedly between temperate species when animals graze them at high pasture allowances and it is other nutritional factors such as retention time of pasture in the rumen and metabolic products of digestion which determine the level of intake. In these conditions then, pasture quantity is the main factor which limits consumption while in temperate rangeland ecosystems overall vegetation quantity is rarely limiting and factors like digestibility of different plant species, their spatial distribution and seasonal growth probably limit the nutrient intake more (Grant and Maxwell, 1988).

Therefore pasture characteristics, such as pasture mass, pasture allowance or residual pasture and pasture height will be important determinants of intake (Bircham, 1981; Hodgson, 1985b). On temperate swards, pasture mass influences the intake response curve primarily by altering pasture height rather than pasture density, the two components of pasture structure (Poppi *et al.* 1987), by influencing the ease with which the animal can prehend herbage. Evidence from many studies (Black and Kenney, 1984; Penning, 1986; Mursan, Hughes, Nicol and Sugiura, 1989; Penning *et al.*, 1989; Burlinson *et al.*, 1991; Penning *et al.*, 1991a) indicates that bite weight and daily herbage intake are closely correlated with sward surface height (Figures 2.7a and 2.7d). Thus on temperate swards, control of sward height has proved to be an effective management tool (Hodgson, 1982b; Hodgson, 1986; Hodgson, Mackie and Parker, 1986b) while on tropical pastures, because of the lower bulk density and higher stem content, density (pasture weight per unit volume of pasture canopy) rather than pasture height is the main determinant of intake per bite (Stobbs, 1973a,b; Chacon and Stobbs, 1976).

Responses in intake (expressed relative to live weight) and in ingestive behaviour to changes in sward structure appear to differ between ruminant species. Sheep respond to a low sward height by taking more bites per minute, although there is always a surface height below which these compensatory measures cannot counter the reduced intake per bite and consequently daily intake falls (Hodgson, 1985a; Penning, 1986; Thompson and Poppi, 1990)(Figure 2.7d). The point at which this threshold is reached varies with forage species, growing season, length of grazing period (a component of daily intake), and animal species as seen by Stobbs (1973b), and Forbes and Coleman (1987), working with cattle on tropical and temperate standing pastures. Goats are more sensitive than sheep to a reduction of pasture mass or sward height on sown swards (McCall and Lambert, 1987; Nicol, Poppi, Alam and Collins, 1987; Huston, Engdahl and Bales, 1988; Merchant and Riach, 1994). Goats also show a strong reluctance to graze below 1000 kg DM/ha (McCall and Lambert, 1987).

Arosteguy (1982) found that sheep were better able to maintain intake on short swards than cattle when continuously grazing on similar sown swards while in contrast, Collins and Nicol (1986) observed that cattle were better able to maintain intake as pasture mass declined when they grazed down a sward under a rotational grazing system than were sheep or goats. The apparent conflict in these results may be due to differences in sward structure and density. Under the rotational grazing system of Collins and Nicol (1986) the sward may have been less dense and this may have been advantageous to cattle since as Forbes and Hodgson (1985a) indicated, the use of the tongue by cattle to pull pasture into their mouth may give them a distinct advantage at higher pasture mass or in less dense pastures.

Wright and Whyte (1989) indicated maximum individual cow and calf performance at a sward height of 9-10 cm and Hodgson (1986) recommended pasture heights 7-10 cm for cattle for maximum intake. Wright and Russel (1987) also found with beef cows and calves that a difference in sward height of 8.5 cm compared to 5.3 cm led to a difference in calf live weight gain of 0.34 kg/day because of the reduction both in the milk yield of the dam and of the herbage ingested by the calves.

Ewes on grass/clover swards of 2 cm, 4 cm and 6 cm sward height increased grazing time rather than biting rate in relation to those on an 8 cm sward (Morris, Parker, Blair and McCutcheon, 1993). Forbes and Hodgson (1985a) stated that sheep increased their bite rate and grazing time more than cattle as pasture mass declined. Furthermore, under changing sward conditions, Jamieson and Hodgson (1979b) observed that the pattern of herbage intake on lambs was similar to calves, although lambs appeared the most sensitive to sward height because their bite rate increased more rapidly as pasture height and mass declined. Orr, Parsons, Treacher and Penning (1990) suggested that the optimum sward surface height for sheep on mixed swards of white clover and grass is about 6 cm and that at this height herbage production and utilization will be optimized and clover content maintained at a low but satisfactory level. Therefore, for continuous grazing Hodgson (1986) suggested pasture heights of 5-6 cm for sheep for maximum intake.

In contrast when weaned lambs were compared with older sheep, Allden and Whittaker (1970) suggested that the smaller mouth size of lambs may give them an advantage when grazing short pastures while larger mouths may be better suited to taller pastures although Illius and Gordon (1987) postulated that young animals may have a larger incisor

breadth per kilogram of live weight than adults. There would appear to be good evidence that weaned lamb growth rates will increase, as sward height increases from 3 to 6 cm (Penning, 1986; Doney, Milne, White, Colgrove and LLoyd, 1987; Maxwell and Treacher, 1987; Orr *et al.*, 1990). Chestnutt (1992) and Grenan (1992) found a pasture height of about 9 cm resulted in a growth rate of 170 g/day in weaned lambs with -20, 105 and 150 g/day growth rate on swards at 3, 5 and 7 cm. Additionally, Rattray, Jagusch, Duganzich and Maclean (1982) showed that milk production of lactating ewes at low herbage allowances was sustained at the expense of body reserves, thus helping to protect the lamb from the direct effect of herbage restriction. Parker and McCutcheon (1992) reported an increased herbage consumptioned of 0.9-17.6% in twin-rearing ewes compared to single-rearing ewes. Maxwell and Treacher (1987) suggested a minimum sward height of 4 cm to avoid a reduction in the potential performance of suckling lambs. Several studies have examined the growth rates of suckling lambs with their mothers on swards declining and increasing in height or being maintained at a constant height. Lloyd and Swift (1987) found the highest live weight gains (305 g/day) on swards maintained between 4 to 6 cm compared to those which decreased in height within the same range (240 g/day). Vipond, Milne, Swift, Fitzsimons, McClelland and Hunter (1989) found a growth rate of 195 g/day on a sward allowed to increased in height with a mean of 5.3 cm versus a rate of 95 g/day on a sward maintained at a mean height of 4.3 cm during July and August although Wilkinson and Mackie (1988) did not find any difference in the performance of suckling lambs on a sward allowed to increase from 6 to 8 cm than on one maintained at 4 to 6 cm in July and August. Finally, Parker and McCutcheon (1992) reported that twin lamb growth rates were similar during the first 6 weeks of lactation at constant sward heights of 3.5, 5.0, 6.0, 7.0, and 8.5 cm but from days 46-

76 of lactation, lambs on the 5.0 cm and longer swards grew faster (240 g/day) than those on the 3.5 cm sward (197 g/day). They concluded that swards of 5-7 cm height during lactation maximize performance in twin-suckling lambs.

Intake and performance responses of goats were linear up to around 10 cm on mixed sown swards (Merchant and Riach, 1994) although goats achieved satisfactory intakes at sward heights 3-4 cm on green and leafy pastures. Clark *et al.* (unpublished, cited by Illius and Gordon, 1993) and Gong, Hodgson, Lambert, Chu and Gordon (1993) observed that goats had shallower bites than cattle and sheep respectively from the sward surface. The primary influence on goats, as recorded by Collins and Nicol (1986), was to reduce total DM intake. There are obvious differences in the grazing preferences of goats and sheep (Lambert, Jung, Fletcher, Budding and Costall, 1989) which are most markedly expressed when browse is present or as herbage availability changes. Under intensive pasture grazing, with no browse species present, sheep may be more willing to move from desirable to less desirable components of the sward as pasture availability is reduced, with the result that they are better able than goats to maintain their DM intake in conditions of declining pasture availability (Nicol *et al.*, 1987).

In summary, selective utilization of areas within pastures as well as of plants and plant parts within these areas make it difficult to determine which component of available forage is regulating intake (Hodgson, 1990). Likewise, variations in intake are difficult to attribute to pasture characteristics because, for instance, height and density as well as nutritive value undergo simultaneous change. However, sheep, cattle and goats seem to respond differently to changes in sward conditions.

2.4.3. Animal factors and intake.

Differences between and within animal species in age, physiological state and nutritional status may affect potential nutrient intake. Animals differ in their physical capacity to eat (intake per bite, grazing time, rumen volume, etc.), in their ability to utilize a given feed and their requirements for nutrients (Hofmann, 1983, 1989; Kay, 1993).

Inherent species differences in gastrointestinal flow dynamics also may influence intake of species which are adapted to particular components of the vegetation (Galyen and Owens, 1989). Demment and Van Soest (1981) and Galyean and Owens (1989) argued that intake is controlled by the amount of dry matter which can be contained in the rumen and the rate at which it disappears from the rumen such that the greater the rumen fill and the rate of disappearance of digesta from the rumen, the greater the intake. Differences in species which influence these parameters have been discussed in Section 2.3.2.3.

The type, weight, physiological state and productivity state of the grazing animal may also be important in determining intake (Figure 2.5; Weston, 1982). Different physiological states will influence the requirement for specific nutrients e.g. high protein requirement in lactation or in young rapidly growing animals (Alam, Poppi and Sykes, 1991). Arnold (1981) stated that high growth potential in young animals, pregnancy, lactation and low body condition all increase grazing time and rate of intake.

Young animals have a higher potential for growth and

from studies in sheep (Allden and Whittaker, 1970) and cattle (Zoby and Holmes, 1983) this may be driven by a comparatively greater physiological demand for energy, although Jamieson and Hodgson (1979a,b) did not find any evidence for this in lambs and calves subjected to low herbage allowance (100 kg OM per ha) on perennial ryegrass swards. Hou (1991) working with penned animals of similar weights, offered 4 pelleted feeds which varied in crude protein concentrations and found that total dry matter intake was greater in the older sheep than in the younger sheep (1997 g/d versus 1736 g/d, respectively) although live weight gain was greater in the younger (318 g/d) than in the older ones (212 g/d).

Cruickshank, Poppi and Sykes (1984) showed that age and live weight in early weaned lambs did not change the proportion of herbage dry matter intake digested in the rumen between 8 and 16 weeks of age. Flores *et al.*, (1989 a,b) provided detailed evidence that previous experience by lambs can influence bite rate and bite size on grasses and shrubs differing in maturity and plant form. Thus, the influence of age within species may be confounded by previous experience.

Because ruminants tend to consume forage in response to physiological requirements, long term intake regulation may be relative to a certain level of homeostasis in body condition. There is no clearly defined relationship between body condition (fatness) and nutrient intake in cattle and sheep (Freer, 1981; Weston, 1982). The general consensus is that lower live weight gains of fat ewes is possibly due to the higher energy value of the live weight gain (more fat, less lean) as animals become fatter and a greater maintenance requirement of heavier ewes. Also, animals in low body condition consume greater quantities of moderate to high-quality forages (compensatory

intake)(Weston, 1982). Additionally, Gibb and Treacher (1983) saw that suckling lamb live weight gains were higher in those whose mothers were in higher body condition state, presumably because of higher milk yields from the ewes. Finally, little information is available on the effects of body condition on the performance of grazing goats on sown swards.

In gregarious animals, such as sheep, social interactions between individuals may influence the grazing behaviour and herbage intake of individuals within a group. It has been postulated that in wild animals dominant animals tend to have higher daily intakes than the rest of the herd or flock (Morley, 1981). Penning *et al.*, (1993a) working with sheep showed experimentally that intake of herbage was reduced for animals grazing in groups of less than four although Rook and Penning (1991a,b), did not find that the duration of grazing bouts of sheep was affected by social facilitation.

2.5. Grazing management.

Grazing management should aim to provide a supply of nutritious herbage over the growing season at low cost, avoid physical waste of herbage and inefficient utilization by the animal, and maintain the productive capacity of the sward (Holmes, 1989; Pearson and Ison, 1989).

Management can affect sward structure through the selection of grassland species and choice of the intensity of grazing. Pearson and Ison (1989) suggest that management should achieve a grassland of moderate height, high density and high leafiness.

2.5.1. The role of white clover.

At present, white clover is perhaps the most important forage legume in the temperature zones of the world. While producing high quality feed, its principal role lies in its ability to supply efficiently the large quantities of nitrogen (N) essential to sustain highly productive pastures (Thomson, 1977; Frame and Newbould, 1986; Frame, 1987; Brock, Caradus and Hay, 1989; Frame and Tiley, 1991). Davies (1992) points out that it can be expected to supply roughly an annual amount of 150-200 kg N/ha to pasture but this does depend on the clover content of the sward, which can vary greatly (Frame and Newbould, 1986).

Additionally, grass/clover swards may be environmentally 'safer' than grass heavily fertilized with N, since the flow of N in grazed grass/clover pastures may be more precisely regulated (Frame, 1987; Jones, 1992) and there may be saving of fossil fuels required in the production of fertiliser N (Connolly, 1993). Thomas (1992) indicated that a clover dry matter content of 20-45% in pasture could provide the N requirements for a productive and sustainable sward.

The maintenance of a significant proportion of clover within the pasture may result in lower pasture growth rates compared with all grass swards receiving high amounts of N because of the lower growth rates of clover than grass (Pearson and Ison, 1989; Davies, 1992) but Robson *et al.* (1989) showed that the difference in yield compared with fertilizer N levels of 150-200 kg/ha on pure grass swards was not great. Although Woledge, Davidson and Dennis, (1992) argued that dietary selection for clover can only be maintained by higher net herbage production of clover

relative to grass, the increased live weight gains on grass-clover swards compared with pure grass swards (a 20% increase for cattle and 20-30% for sheep) may offset the loss in herbage productivity and the consequent reduction in stock carrying capacity (Davies, 1992; Frame, 1992). The intake of temperate legumes is invariably greater than that of temperate grasses, particularly with sheep, and this is the major reason why animal production either of meat or milk is usually greater on legumes than on grasses (Thomson, 1984).

These higher intakes of clover are associated with a shorter retention time in the rumen (Ullyat, Lancashire and Jones, 1977). Also, the quantity of protein digested in the small intestine is greater with clover than with ryegrass containing similar amounts of protein. White clover also has a higher ratio of soluble to structural carbohydrate than grasses and most other legumes (Ullyat, 1981; Thomas, 1987; Frame, 1987; Brock *et al.*, 1989). Consequently, Fulkerson, Slack, Moore and Rolfe (1993) concluded that high rates of output can be achieved from grass-clover swards without input of nitrogen fertiliser.

Live weight gains of lambs fed on white clover exceeds those fed on most other herbages or when predominantly white clover swards are grazed compared to ryegrass swards (Gibb and Treacher, 1976; Marsh and Chestnutt, 1976; Thomson, 1979; Ullyat, 1981; Gibb and Treacher, 1984; Davies and Evans, 1986; Davies, Fothergill and Jones, 1989; Chestnutt, 1990; Davies, Fothergill and Morgan, 1992; Chestnutt, 1992; Vipond, Swift, Noble and Horgan, 1993b), although Orr *et al.* (1990) found little difference in performance of suckling lambs at equal sward height between grass/clover and N-fertilized grass swards. Howard, Griffiths and James (1990), and Vipond, Swift, McClelland, Fitzsimons, Milne and Hunter, (1993a) associated

significant increases in carcass weight of lambs with grazing ryegrass/clover pastures after weaning. In general, on grass/clover swards the live weight gain of lambs can be increased by about 20% above that achieved on grass alone.

The success of a grass/clover sward is also dependent on the ability of the farmer to maintain a grass/clover balance without loss of the companion grass in order to utilize the nitrogen transferred from the white clover (Evans, Williams and Evans, 1992). An appropriate defoliation regime is needed to keep this balance (Laidlaw *et al.*, 1992).

2.5.2. Multispecies grazing.

Section 2.3.2.3 discussed how different ruminant species have adopted different foraging strategies over evolutionary time or as a consequence of selection imposed by man. This leads to the fact that ruminants can occupy different niches (Owen-Smith, 1985; Gordon, 1989; Gordon and Iason, 1989; Milne, 1991; Illius and Gordon, 1993).

Selective grazing, as has been explained, is displayed to varying degrees by all wild and domestic herbivores. This selective utilization of plant species and parts by herbivores in grazed systems frequently decreases harvest efficiency, energy flow within the grazing food chain, and ultimately production of regrowths (Briske and Heitschmidt, 1991).

Therefore, grazing induced modifications of plant species composition can greatly affect livestock production depending on the specific plant community and management

goals. Selectivity by an animal may be influenced by the presence, either concurrently or previously, of one or more animal species in the area, either by changing the short-term relative availability of the different plant species (Holland, Parton, Detling and Coppock, 1992) or differentially affecting the palatability of the remaining forage (Sala, 1988; Vallentine, 1990; Milchunas, Lauenroth and Chapman, 1992; Pacala and Crawley, 1992).

2.5.2.1. Mixed grazing.

Mixed grazing involves at least two different animal species simultaneously grazing the same area. Lambert and Guerin (1989) claimed theorical advantages when animals graze together because of (i) incomplete dietary overlap amongst animal species, (ii) increased efficiency of grazing, (iii) botanical composition manipulation, (iv) generalized effects of different seasonal energy-requirements profiles of animal species, (v) reduced gastro-intestinal parasite burdens and (vi) farm and financial management benefits.

2.5.2.1.1. *Animal performance.*

The effects of multi-species system on livestock production has been the subject of many studies throughout the world (Aucamp, Danckwerts and Tainton, 1986). Generally speaking a positive effect on animal production has been related to mixed grazing. Taylor (1985) and Merrill, Reardon and Leinweber (1968), working on indigenous pastures on the Edwards Plateau region of Texas for nearly 40 years, showed the relative effects of

variation in grazing pressure on livestock production. Individual cattle and sheep performance was higher when they grazed in combination with goats than when they grazed alone: cattle preferred grass, whilst sheep preferred grass and forbs and goats preferred browse and grass. If desirable browse species are maintained and stocking ratios properly balanced, little competition occurs between cattle and goats. The same is true for sheep and cattle or sheep and goats if an abundant and stable source of forbs is provided to the animals (Merrill and Taylor, 1981; McCall and Shaw, 1991; Stuth, 1991). Under semi-arid conditions in Senegal and a mixed management of goats, sheep and cattle, there was clear evidence of differential selection of grasses and woody material by the three animal species (Connolly, Nolan, Dione and Sall, 1993; Nolan, Connolly and Sall, 1993). Anderson, Smith and Hulet (1985) concluded that multispecies grazing of indigenous swards with cattle and sheep throughout the year enhanced the use of standing crop and was complementary rather than competitive. However increases in grazing pressure by one animal species can force another animal species to select their less preferred food resulting in reduced performance, decreased harvest efficiency or both.

Studies of mixed versus separate grazing on grass/legume pastures have usually been concerned with mixed grazing by cattle and sheep and were reviewed by Nolan and Conolly (1977), who reported increased animal output/ha between 10 and 20% from mixed systems. However, Nolan (1982) reported several experiments in which the improvement in live weight gain of mixed grazed lambs and steers was between 0-33% and 6-31% respectively with an increase in output per hectare of 28.5% for sheep and 10% for cattle. When mixing cattle and sheep, Nicol and Souza (1993) also improved lamb and steer growth rates by nearly 10% because sheep consumed up to 40% of the total dry

matter refused by steers although conversely Dixon, Frame and Waterhouse (1986) recorded similar outputs from pastures grazed by cattle only and by cattle and sheep. They suggested that cattle would be beneficial in maintaining the pasture height at the optimum of 4-5 cm for sheep.

Few studies have been reported with goats although in Australia McGregor (1985) reviewed the complementary grazing of goats with sheep or cattle on sown swards of annual ryegrass, barley grass and subterranean clover. He found that Merino wether sheep grazed with Angora wether goats in a 1:1 ratio grew 10% more wool per head. However, Nicol, Russel and Wright (1993) found no increase in live weight gains of sheep or cattle grazing with goats on sown pasture possibly because there was not a high enough stocking rate of goats to show any changes in diet composition. Collins (1989) suggested that complementarity of behaviour between mixed species may only occur at particular times of the herbage growth cycle with respect to pasture species balance and sward structure.

On sown swards, Collins (1989) showed experimentally that when cattle grazed with goats in a 50:50 ratio of metabolic bodyweight they both increased their dry matter intake, demonstrating complementarity behaviour. Also, Van Dyne, Brockington, Szocs Duek and Ribic (1980) recorded a lower dietary overlap (0.50) between cattle and goats than between cattle and sheep (0.80), and therefore the potential for complementarity was greater. Finally, Townsend and Radcliffe (1990), working with lambs grazing with goats and sheep, recorded higher live weight gains as the goat to sheep ratio increased.

2.5.2.1.2. *Pasture production.*

Nolan (1982) and Arosteguy *et al.* (1983), among others, implied that enhancement of pasture growth was a reason for increased animal productivity in mixed grazing.

Boswell and Cranshaw (1978) recorded an increase in pasture production of 2.5 tons/ha/annum on ryegrass/clover swards from a cattle plus sheep pasture over the single sheep and cattle pastures but Hodgson, Arosteguy and Forbes (1986a) failed to show any increased levels of herbage production on perennial ryegrass swards. Arosteguy *et al.* (1983) and Monteath, Johnstone and Bosell (1977) suggested that sheep pastures intrinsically produce more DM than do cattle pastures because the tiller populations density is higher.

It can be concluded that more information is needed to assess the potential of using goats in particular in mixed-stocked grazing systems based on grass/legume swards.

2.5.2.2. Sequential grazing.

Sequential grazing involves two (or more) animal species grazing a common area of land at different times. The timing of when an animal utilizes the pasture in relation to other animals of the same species is an important determinant of the quality of forage selected and probably nutritient intake (Coppock, Ellis and Swift, 1986; Vallentine, 1990).

Temporal variation in grazing strategies is related primarily to the short- and long-term effects of

defoliation on quantity of forage produced (efficiency of energy capture) and consumed (harvest efficiency), and secondarily to the quality of forage produced and consumed (efficiency of conversion; Heitschmidt and Taylor, 1991; Langvatn and Hanley, 1993). Competition for food between livestock or herbivorous wildlife varies over time and space as a function of demand relative to the quantity and quality of forage available (McNaughton, 1986; McNaughton and Sabuni, 1988; Barnes, Heitschmidt and Varner, 1991; Rittenhouse, 1991).

Natural grazing succession may play a part in circulating grazing pressure and preventing localized overgrazing (Novellie, 1991). Studies on natural environments in North America (Anderson and Scherzinger, 1975; Collins and Urness, 1983; Urness, 1982) with elk and mule deer and in the Serengeti, Kenya (Blankenship and Overton, 1974) with Thompson's gazelle showed an improvement in the quality and pasture structure of the forage available for these herbivores by previous livestock grazing. Similar relationships have been shown between sympatric wildlife species such as blue wildbeest, zebra, and Thompson's gazelle (McNaughton and Sabuni, 1988) and horses, sheep and goats in the Himalayas (Negi, Rikhari, Ram and Singh, 1993) and bushbuck, cattle, duiker, gelada, horses, klipspringer and Walia ibex in Ethiopia (Dunbar, 1978). In Serengeti savanna, Gwynne and Bell (1968), Bell (1969, 1970, 1971), Jarman and Sinclair (1979) and McNaughton, (1976, 1978, 1979, 1985) demonstrated how different species of ungulate select different plant parts from the same plant species. Murray and Brown (1993) showed that the composition of these natural grass swards and their growth stage affects the foraging efficiency of wildebeest, topi and hartebeest and then determined their ecological separation (niche separation). This habitat segregation reduces competitive overlap: large bulk grazers

facilitate access to shorter grass by smaller species (Gordon, 1989; Novellie, 1991; Owen-Smith and Cumming, 1993). Du Toit (1990) investigated the use of different feeding-height levels in the natural vegetation on Kruger National Park (South Africa). Giraffe, kudu, impala and steenbok showed a clear stratification in their feeding habits through the seasonal cycle. Thus sequences of animal species are a common phenomena in natural grazing ecosystems and can facilitate feeding of different animal species.

Differences in diet selection between different species and their impact on sward composition and structure may offer opportunity for manipulating the clover contents of grass/clover swards by appropriate sequences of animal species. For example, in grazing studies involving sheep it is rare for the level of white clover in grass/clover pastures to rise above 30%. However, Alder, Cowlishaw, Newton and Chambers (1967) and Briseño de la Hoz and Wilman (1981) reported high levels of clover content in pastures grazed by cattle. For example, grazing with cattle compared to sheep will increase the clover content of the pasture (Wright, Jones and Parsons, 1992). McCall, Semeaton, Gibbison, McKay and Hockey (1986) also measured significantly more clover stolon in cattle pastures than sheep. Clark (unpublished data, cited by Illius and Gordon, 1993) reported that cattle grazed to lower levels than goats but tended to leave more clover in pastures which can benefit sheep.

The apparent dislike of goats for clover appear to offer opportunities for increasing sheep and cattle output either in mixed grazing systems or in a sequential grazing systems on temperate grass/clover pastures (Clark *et al.*, 1982; McGregor, 1985; Collins and Nicol, 1987; Lambert, Clark and Rolston, 1987; Radcliffe and Francis, 1988;

Radcliffe *et al.*, 1991). Also, the grazing management of sheep and cattle is dictated to a large extent by the need to prevent seed-head formation which affects pasture quality and productivity. This can be avoided by goat grazing (Russel *et al.*, 1983; Grant *et al.*, 1984; Russel and Lippert, 1987). Radcliffe *et al.* (1991) and Collins and Nicol (1987) found that on ryegrass-clover swards the pasture remaining after grazing with goats had relatively more leaf than the pasture remaining after grazing with cattle (higher stem and clover fraction) or with sheep. Therefore, Radcliffe *et al.* (1991) recommended that cattle or sheep should follow goats for best utilization of the clover.

This complementary nature of sheep, goat and cattle grazing behaviour suggests the possibility of increased meat, fibre and wool production. Bown, McCall, Scott, Watson and Dow (1989) reported that doe goats grew twice as fast when high-producing pastures were grazed by a following mob of cattle and sheep, compared to goat-only grazing systems. Also, improved lamb growth has been associated with higher clover contents in pastures grazed with goats in the preceding spring (Radcliffe and Francis, 1988) or with cattle (Wright *et al.*, 1992) compared to pastures previously grazed with sheep. However, as pointed out by Collins and Nicol (1987) the potential for dietary complementarity between cattle, sheep and goats is highly dependent upon the state of the pasture being grazed.

2.6. Summary.

Herbage quality, sward structure, animal intake and diet selection are closely linked. The goals of grazing management have been identified as those which: (i) match

the seasonality of available feed with the pattern of intake and with the selective behaviour of the animals, (ii) maintain a high quality of feed and a desirable sward structure, particularly with respect to light interception, height, leafiness, and density and (iii) optimize the management of the grassland species with the manipulation of herd structure.

It has been shown that producing pastures of higher white clover content by manipulation of the species of grazing animal may be possible and needs further evaluation. Not only is there a role for white clover swards on low-input sheep and beef, lowland and upland, enterprises but there may be a role for goats to enhance the clover content of the sward in which fertilizer N may be used only strategically and sparingly.

Changes in animal species by a sequential grazing management may would allow sward conditions to be manipulated to induce desirable changes in both sward production and composition. Grazed grass-clover swards provide a useful model system to test the complementarity of sheep, cattle and goats under a sequence of different animal species at different times and thereby to improve our understanding of the processes by which these supposedly different foraging behaviours could modify the development of clover in low-input sown swards. It has been argued that it is important to identify the sward structure responses to their activities.

CHAPTER 3

EXPERIMENT ONE

The effect of animal species on sward composition and on the diet selected by a subsequent animal species grazing grass/clover swards.

3.1. Introduction.

The review of the literature indicates that the diet selected by grazing animals results from a combination of sward and animal factors. In particular there are differences between animal species which may be sufficient to result in changes in the botanical composition and canopy structure of swards. It suggests that differences in the balance of grass and clover and in their spatial arrangement might occur under grazing by different animal species. Thus, choice of grazing species may be an important factor in the management of grass/clover swards.

The main objective of this experiment was to identify the changes in the sward components and canopy arrangement that occur on grass/clover swards when grazed by different domestic livestock: cattle, sheep and goats, and their potential facilitating implications on the diet selected by a subsequent grazing species: sheep or goats.

3.2. Materials and methods.

3.2.1. Site.

The experiment was conducted in one field at the Macaulay Land Use Research Institute's Hartwood Research Station, situated near Shotts, Lanarkshire (map reference NS 848602) in central Scotland during 1991.

The soil is of a clay loam type with impeded drainage and classified in the Rowanhill Soil Series: a poorly draining non-calcareous gley soil developed on a clay loam layer derived from sedimentary rocks of the Carboniferous Period characterised by low levels of available phosphorus and medium levels of available potassium.

The farm lies between 150-300 m above sea level. The average rainfall is 1066 mm per year. The generally wet, cool conditions give rise to a comparatively short growing season, with about 200 days when soil temperatures exceed 6° C.

3.2.2. Experimental design.

Three different animal species (pre-species): cattle (Prsp-C), sheep (Prsp-S) and goats (Prsp-G) continuously grazed a ryegrass/white clover sward in separate paddocks of 1.0, 0.4 and 0.4 ha respectively at a target sward height of 6 cm from the 23 May to 28 July (Phase 1). There were two replicate paddocks for each animal species treatment, i.e. 6 paddocks in total in Phase 1. Treatments were allocated to paddocks at random within each replicate

but no two paddocks with goats were adjacent (see Figure 3.1a)

On 29 July, each sheep and goat paddock was subdivided into two plots of 0.2 ha while two plots of 0.2 ha were created in each of the cattle paddocks. Each plot was grazed by sheep (Sp-S) or goats (Sp-G) from 29 July until 2 September (Phase 2; see Figure 3.1b).

The experiment had thus a 3 x 2 factorial design, i.e. three animal species in Phase 1 and two animal species in Phase 2. To avoid confusion the term 'paddock' has been used to refer to the experimental areas in Phase 1 and 'plot' for the experimental areas in Phase 2.

3.2.3. Sward.

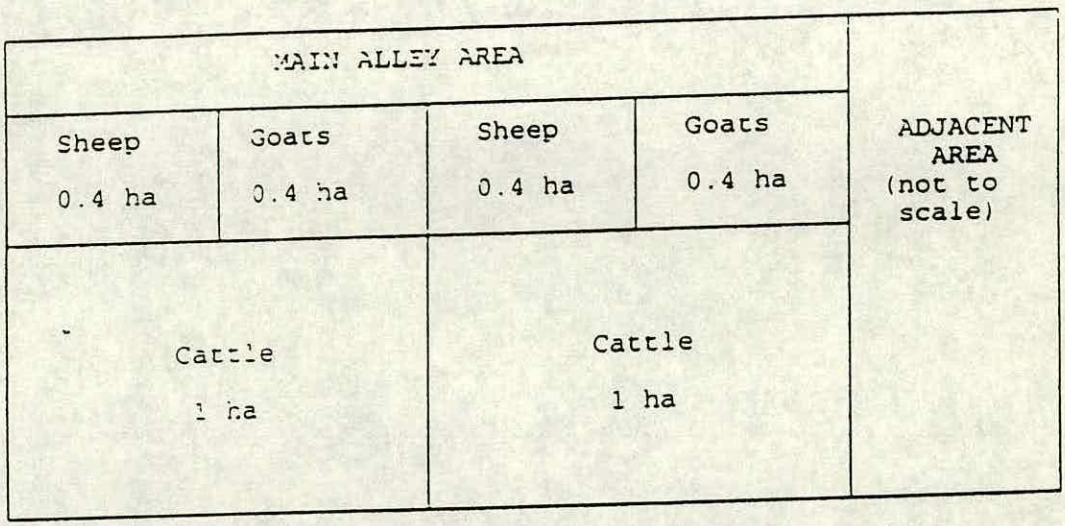
The experimental area consisted of a perennial ryegrass-(*Lolium perenne*) dominant and white clover-(*Trifolium Repens*) sown sward mixture. On 15 May 1989, 28 kg/ha of a mixture of early and late flowering perennial ryegrass was sown while on 8 July 1990, 5 kg/ha of white clover was slot-seeded into the established sward (see Table 3.1).

In April 1991, a light dressing of cattle slurry supplying approximately 14 kg/ha of N, 4 kg/ha of P and 23 kg/ha of K was applied. Granulated compound fertiliser was applied twice thereafter: an application of 36 kg/ha of N, 18 kg/ha of P_2O_5 and 18 kg/ha of K_2O on 18 April and a later application on 24 July of 60 kg/ha of P_2O_5 and 60 kg/ha of K_2O.

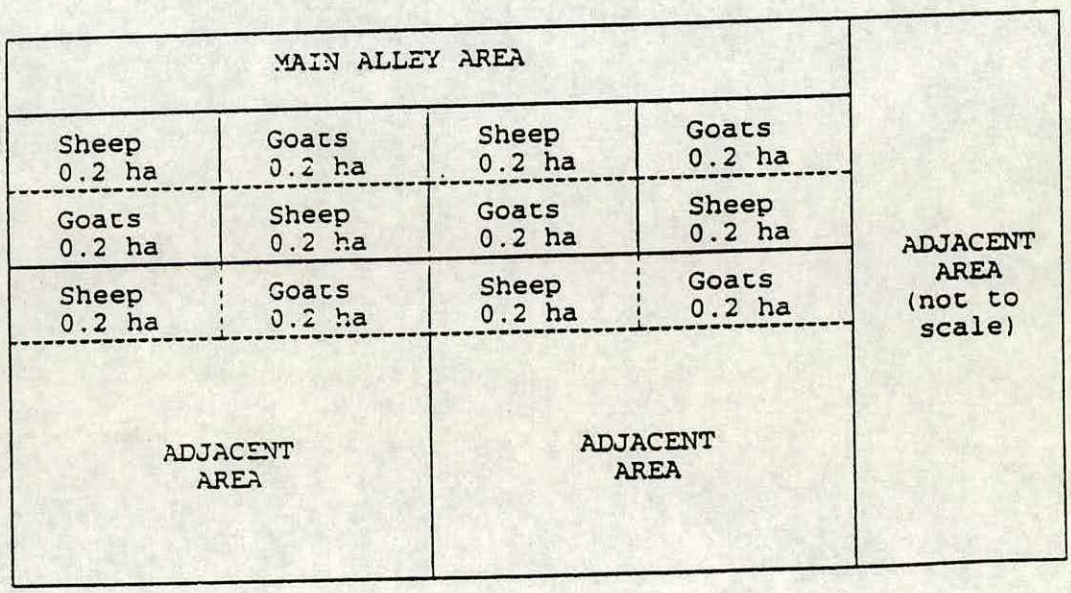
Figure 3.1. Plan (approximately to scale) of the experimental layout of the two phases of Experiment 1:

a) sheep, goat and cattle paddocks in Phase 1
b) sheep and goat plots in Phase 2

a) Phase 1.



b) Phase 2.



———————— Permanent fence erected throughout the experiment (Phase 1 and Phase 2).

- - - - - - - - - - - - - - Fence erected at the end of Phase 1.

Table 3.1. Details of re-seeding of swards used in Experiment 1.

Sowing Date	Species	Variety	Seed rate per ha (kg/ha)
15 May 1989	perennial ryegrass	Baranna	6.0
	"	Condesa	6.0
	"	Contender	4.0
	"	Duramo	4.0
	"	Macella	8.0
8 July 1990	white clover	Rivendel	2.5
	"	Kent Wild White	2.5

3.2.4. Animals.

Phase 1

A maximum of 79 goats, which were approximately 14 months old at the start of the experiment, were used. They were castrated males of a range of genotypes containing 0.25-0.50 Scottish Feral and 0.75-0.50 exotic genes of Tasmanian, Icelandic or New Zealand origin. They were allocated to paddocks by restricted randomization balanced as far as possible for genotype and live weight.

A maximum of 30 Greyface (Blue-faced Leicester x Scottish Blackface) ewes with 43 Suffolk-cross lambs born in March 1991, were used, allocated at random to paddocks but balanced for ewe live weight. Twenty Charolais-cross yearling steers born in March/April 1990, were allocated at random according to their age and live weight to the two paddocks. An additional five mature Hereford-Friesian cows and their Charolais-cross calves, born in September/October 1990, had to be used for a short period to impose the appropriate sward height.

Phase 2

The sheep used in Phase 2 were 50 yearling Greyface female sheep (gimmers). They were also randomly allocated to each plot. The goats were the same flock of yearling castrated goats which had been used in Phase 1.

An additional six yearling castrated male goats and six Greyface gimmers from the same flocks of animals used

in Phase 2 were oesophageally fistulated.

3.2.5. Management.

Paddocks were stocked when the mean sward surface height of treatment paddocks reached 6 cm on 23 May. The initial stocking rate for all the species was calculated according to the mean energy requirements of the animals (AFRC, 1993), adjusted for the energy costs of grazing, and an estimate of herbage growth rate. A target sward surface height of 6 cm was maintained on all paddocks by regular adjustment of animal numbers in both Phase 1 and 2. An adjacent area in the same field was grazed by animals not on the experimental area.

All the sheep and goats were dosed every five weeks with an anthelmintic 2.5% w/v Fenbendazole (Panacur, Hoechst Animal Health, UK) and were treated with an ectoparasiticide 6.0% w/v Cyromazine (Vetrazin, CIBA-GEIGY Agriculture, UK) at the start of the experiment and at the beginning of Phase 2. The cattle were treated with Ivomec three weeks after turn-out.

Water and a mineral lick supplement were available to each group of animals. One shelter per group of goats was provided to protect the goats from rain and wind.

3.2.6. Pasture measurements.

3.2.6.1. Sward height.

The surface height of the undisturbed sward was estimated twice weekly using the HFRO sward stick (Barthram, 1986). The mean height of the sward in a paddock or plot was calculated from 50 measurements of the first contact with green leaf obtained randomly when walking a 'W' shaped path through each paddock or plot. On the basis of these height measurements, animal numbers on each paddock or plot were immediately adjusted as necessary to maintain the swards as near as possible to a target sward height of 6 cm.

3.2.6.2. Sward composition.

Sward composition was measured on three occasions during the experiment: at the end of Phase 1 (22-24 July; Period 1) and in the middle (5-12 August; Period 2) and end (26 August-2 September; Period 3) of Phase 2.

These measurements were designed to provide estimates of the vertical structure of plant species and plant components in short, medium and tall areas of each paddock (Phase 1) or plot (Phase 2).

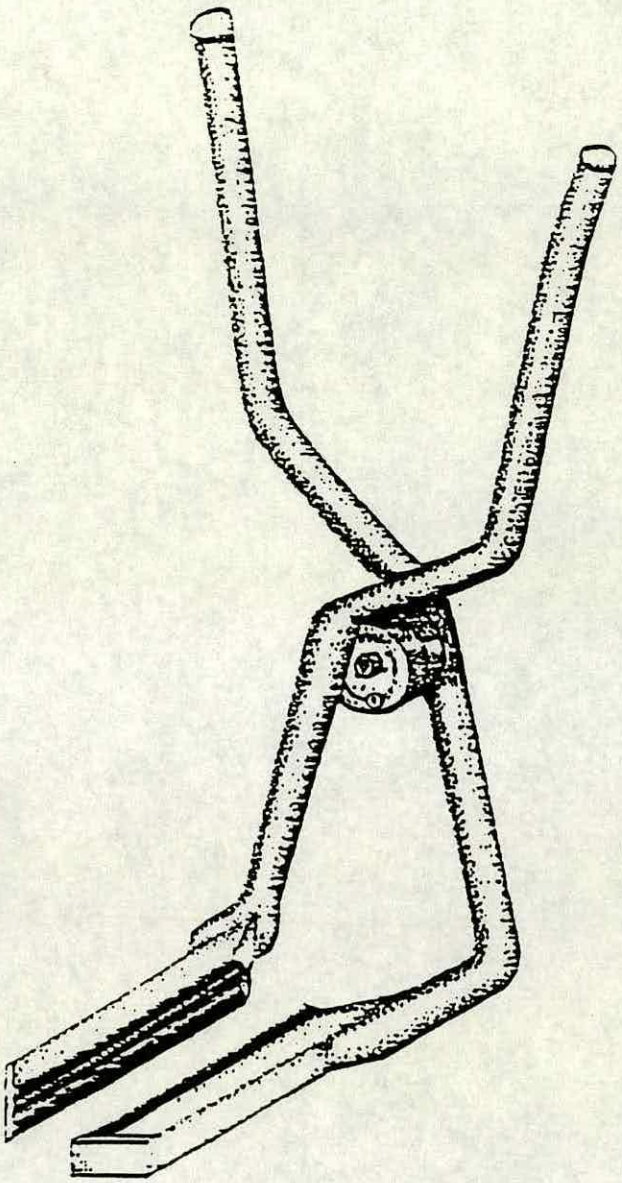
This was done using a sward gripping device (Barthram, 1992). Twenty-four samples were located at random when walking a 'W' shaped path through each paddock (Phase 1) or plot (Phase 2). The gripper equipment (made by Mr. N. Turnbull Scottish Centre for Agricultural

Engineering, Bush Estate, Penicuik, Midlothian, UK), consisted of a pliers-like instrument with parallel gripping surfaces which are lined with corrugated rubber (see Figure 3.2). When open, the gripping surfaces delineated a rectangular area of 20 cm^2. The arms were slid into the sward at ground level causing minimum disturbance. The jaws were closed and gripped the sward and the herbage was cut at ground level with hand shears. Any entangled, but ungripped, material was removed and the sward sample was cut into four different horizontal layers (horizons) every 2 cm from the base upwards. To achieve this, plastic boxes were used with a box for each horizon fitted with wooden batons as guides to ensure that the horizontal cuts were made at the correct heights on the sample (Barthram, 1992; Barthram and Grant, 1994; see Plate 3.2). Each sample was therefore divided into horizons of 0-2, 2-4, 4-6 and >6 cm above ground level.

Prior to cutting each sample to ground level, three sward heights were measured within it with the HFRO sward stick, recorded and used to calculate the mean height of each sample (see Plate 3.1).

Subsequently, on each paddock or plot, all the samples from each horizon were bulked on the basis of the mean sward height of the samples with three height categories of eight samples i.e. short, medium and tall.

Figure 3.2. The gripping equipment.



(From Barthram, 1992)

Plate 3.1- Measuring sward heights in a 20 cm^2 sampled quadrat area, prior to cutting to ground level.



Plate 3.2- Cutting the 20 cm^2 quadrat sample into four horizontal layers (horizons). The wooden batons were used as guides to determine the position for cutting.



The bulked horizons were stored at -20 ^{0}C until washed and manually separated into the following nine components:

- grass leaf
- grass pseudostem
- grass flowerstem
- dead grass
- clover lamina and petiole
- clover flower
- clover stolon
- dead clover
- other species

Each component was oven dried at 80 ^{0}C for 24 hours and the dry weight subsequently recorded and converted to kg DM/ha for each horizon.

3.2.7. Animal measurements.

3.2.7.1. Diet selected.

Estimates of diet selection were obtained from oesophageally fistulated sheep and goats from each plot in Phase 2 on the same days on which sward composition was measured.

3.2.7.1.1. *Oesophageal fistulates: techniques and care.*

Surgical preparation followed the procedure of Bishop and Froseth (1970). Plugs of two designs were used. The first, similar to that described by Stobbs (1973a) and by

Forbes (1982), was a rubber plug on a cord constructed with a polythene collar, fitted into the oesophagus of six sheep and six goats following surgery on 6 June 1991. After the operation the animal were housed for 14 days to allow close observation. From 20 June to 14 July, the animals were kept on pastures similar to and close to the experimental area with a water supply and a mineral lick supplement. The fistula was cleaned at weekly intervals throughout the experiment. The second plug was a split, 'T' shaped rubber cannula (McManus, 1981), replacing the first one when the fistula reached a requisite size at least 3 weeks before the first samples were collected.

From 15 July, one month before their use, the oesophageally fistulated animals were rotated around all plots twice to allow them to become familiar with the swards and with the rest of the experimental animals. Preliminary training was carried out by fitting a polythene collection bag to each fistulated animal without removing the plug. This allowed the fistulated animals to become accustomed to the procedure and the non-fistulated animals to become accustomed to having the fistulated animals with them and so avoid interference during grazing.

Oesophageal extrusa was sampled from each animal by temporarily removing the T-shaped plug before the collecting period and fitting a 200 gauge 530 mm x 660 mm polythene bag around the neck. The animals were then allowed to graze undisturbed for about 15 minutes for each sample collection period. Samples contaminated with rumen fluid were discarded. All acceptable samples were transferred to a 190 mm x 190 mm mini-grip polythene bag and placed immediately in a insulated chilled container before being stored at -20 ^{0}C.

The fistulated animals grazed each plot for 24 hours

before samples were collected from them. During each measurement period, samples were collected from each sheep once on each plot grazed by sheep, i.e. six samples per plot per period. Because only three fistulated goats were eventually available, two samples were collected on each occasion (about 4 hours apart) from each goat, again giving six potential samples per plot.

3.2.7.1.2. *Diet composition.*

Extrusa samples were stored at -20 ^{0}C until required. They were freeze dried to constant weight. Subsequently, the dried sample was thoroughly but gently mixed and a small portion (10 g of DM mass) was subsampled and manually separated into the same components as described for the pasture samples:

- grass leaf
- grass pseudostem
- grass flowerstem
- dead grass
- clover lamina and petiole
- clover stolon
- clover flower
- dead clover
- other species
- unidentified remainder.

Finally, samples were oven dried for 24 hours at 80 ^{0}C and their dry weight recorded. Results were expressed as a percentage of dry matter for each component.

3.2.7.1.3. *'In vitro' digestibility.*

After a portion of the freeze-dried extrusa sample had been subsampled for botanical composition, the remainder of the extrusa sample was ground through a 1 mm screen. A subsample of 3 g of DM mass was subjected to the *in vitro* digestibility procedure described by Tilley and Terry (1963) as modified by Alexander and McGowan (1966). Results were expressed as a proportion of dry matter for each component.

3.3. Statistical analysis.

The data were analysed using Genstat 5.2 (Lawes Agricultural Trust, 1990) and Minitab 7 (Minitab Inc., 1989) statistical packages. Tests for normality were done on the data prior to analysis. Genstat 5.2 was used for analysis of variance (ANOVA) and regression analysis. Minitab was used to perform chi-squared tests.

3.3.1. Sward height.

Comparisons of the frequency distributions of sward height measurements between treatments within each Phase (Phases 1 an 2) were made using a χ^2 test to compare the number of measurements above or below 8 cm. Mean sward heights in Phase 1 were compared using an ANOVA with replicate and pre-species as treatment factors and paddock as a blocking factor. In Phase 2 a hierarchical analysis of variance was used with replicate, pre-species and species (plus the interaction of pre-species x species) as treatment factors and plot nested within paddock as a blocking factor.

3.3.2. Sward composition.

The general procedure was to analyse data for each botanical component separately using ANOVA, with a separate hierarchical nested analysis for each of the three sampling periods (Periods 1, 2 and 3). To test for effects of treatment on overall sward composition, the percentages of the different components were analysed using replicate and pre-species as factors in Period 1 and replicate, pre-species and species (plus the pre-species x species interaction) as factors in Periods 2 and 3 with paddock (Period 1) or plot nested within paddock (Periods 2 and 3) as blocking factors. Also, differences in percentages of each botanical component between sward height categories were analysed with replicate, pre-species and sward height category (plus the interaction of the last two) as factors in Period 1 and replicate, pre-species, species and sward height category (plus the interaction of the last three) as factors in Periods 2 and 3 and sward height category nested within paddock (Period 1) or sward height category nested within plot within paddock (Periods 2 and 3), as blocking factors.

The amounts (kg/ha) of the nine botanical components in each of the four horizons were analysed with replicate, pre-species, sward height category (plus the interaction of the last three) as factors in Period 1 and replicate, pre-species, species, sward height category and horizon (plus the interaction of the last four) as factors in Periods 2 and 3. The blocking factors were the same as those used for comparison of sward height categories. An example of ANOVA is given in Appendix 3a.

In addition to analysing the sward composition as a whole the composition of the 'sward surface' was also

calculated and analysed. Within each sward height category in each paddock or plot, an 'average' sward surface composition was calculated from the composition of each horizon, weighted for the number of sward height measurements (recorded prior to cutting to ground level) in each horizon. This was done by multiplying the weight (kg/ha) of each component in a horizon by the number of height observations falling within that horizon height band. Following the calculation of the totals produced, they were divided by 24 i.e. the number of height measurements in each sward height category (eight quadrats x three height measurements per quadrat).

The percentage of each component calculated, which has been defined as the 'sward surface', was analysed for differences due to treatment and sward height category as described above for total sward composition.

Analyses of variance were also carried out on the differences in percentage of each botanical component between sampling periods.

3.3.3. Diet selection.

Because only three oesophageally fistulated goats were available for each sampling period compared to six sheep, each goat was used to obtain two samples per plot to provide the same total number of samples from each plot for sheep and goats. Consequently when individual animal effects were incorporated in the ANOVA, the data were not balanced. Plot nested within animal was used as a blocking factor in the analysis of variance for each botanical component of the diet selected by either sheep or goats. Data from sheep from both sampling periods (Periods 2 and

3) were analysed with replicate, pre-species and sampling period (plus the interaction of pre-species x period) as factors. Data from goats were analysed separately for each sampling period with replicate and pre-species as factors. Differences between sheep and goats in the percentages of botanical components selected in the diets were analysed for each sampling period by Student's paired t-test comparisons using pooled estimates of the standard errors from the ANOVA to calculate standard errors of differences. *In vitro* digestibility of the diet selected was analysed in the same way.

3.3.4. Comparison of composition of the diet and of the sward.

Regressions were fitted between percentages of total clover in the diet selected by sheep and goats in Phase 2 (Periods 2 and 3) and percentages of total clover in the sward and 'sward surface' by simple and multiple linear regressions. Step-wise regression was used to produce the simplest linear model (i.e. with the fewest variables) that accounted for as much as possible of the variation in the response variable (percentage of clover in the diet selected). It was assumed that percentage of clover in the diet did not depend on interactions between the explanatory variables and their factors.

3.4. Results.

The results are presented in the same sequence as is followed in the Materials and Methods section i.e. sward measurements are presented first, followed by diet composition measurements. When the terms paddock and plot

are quoted, they refer to the treatment areas in Phases 1 and 2 respectively. Also to avoid confusion the terms Prsp-S, Prsp-G and Prsp-C are used to refer the sheep, goat and cattle pre-species treatments in Phases 1 and 2 whereas the terms Sp-S and Sp-G refer to sheep and goat species treatments in Phase 2.

3.4.1. Weather.

Annual rainfall was 1012 mm (95% of average) between January and December 1991. There were dry conditions in April and May (68.5 and 18.5 mm rainfall respectively) and temperatures were low (mean daily temperature of 6.2 and 10.0 ^{0}C respectively) resulting in slow grass growth. However, June was relatively wet (115 mm rainfall) and cool (mean daily temperature of 10.6 ^{0}C). Although July and August were warm (mean daily temperature of 15.2 and 14.8 ^{0}C respectively), some wet spells did occur (104.0 mm and 48.5 mm of rainfall respectively in July and August) during Phase 2 of the experiment. Wetter conditions (101 mm rainfall) occurred in September (see Figure 3.3).

3.4.2. Sward height.

Overall mean sward heights for each pre-species treatment in Phase 1 and Phase 2 are given in Table 3.2 and Table 3.3 and are presented graphically in Figures 3.4 (Phase 1) and 3.5 (Phase 2). Initial differences in sward surface heights between pre-species treatments when sward heights were above target disappeared by the time all paddocks were grazed down to 6.0 cm in early June. From then, differences between pre-species treatments (see Table 3.2) were not statistically significance.

Figure 3.3. Monthly mean temperatures (°C) and rainfall (mm) recorded at the experimental site during 1991.

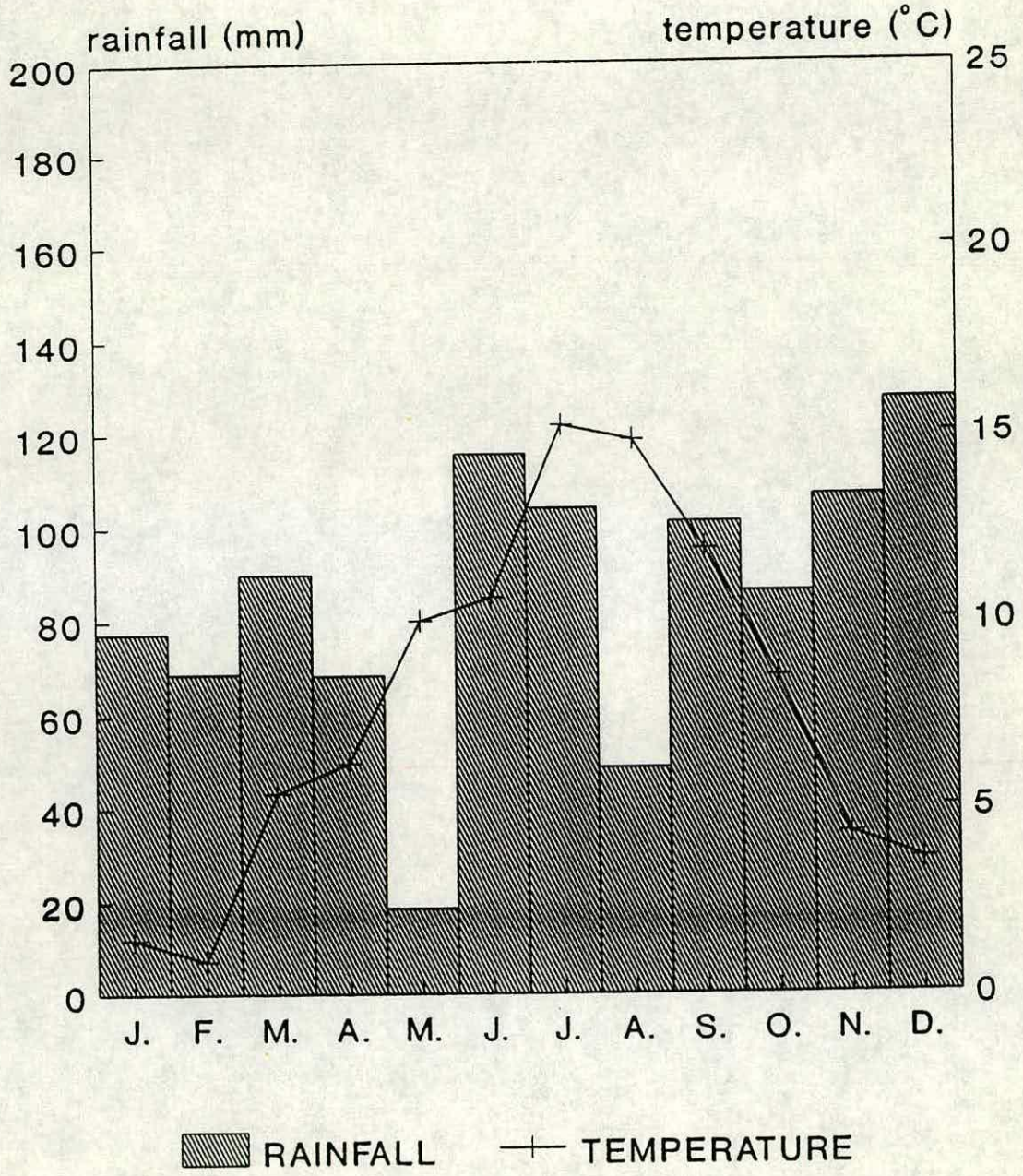
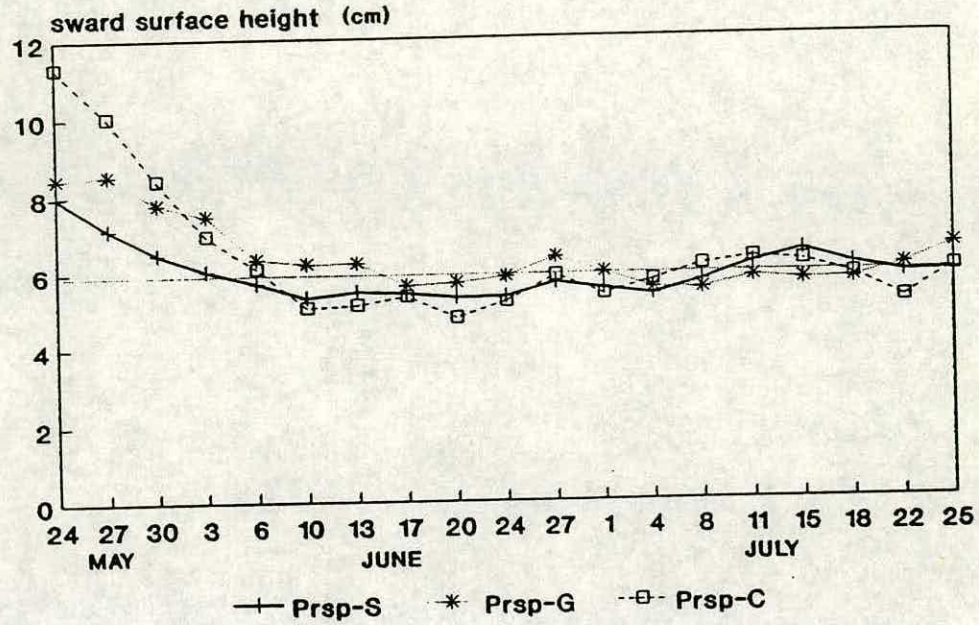
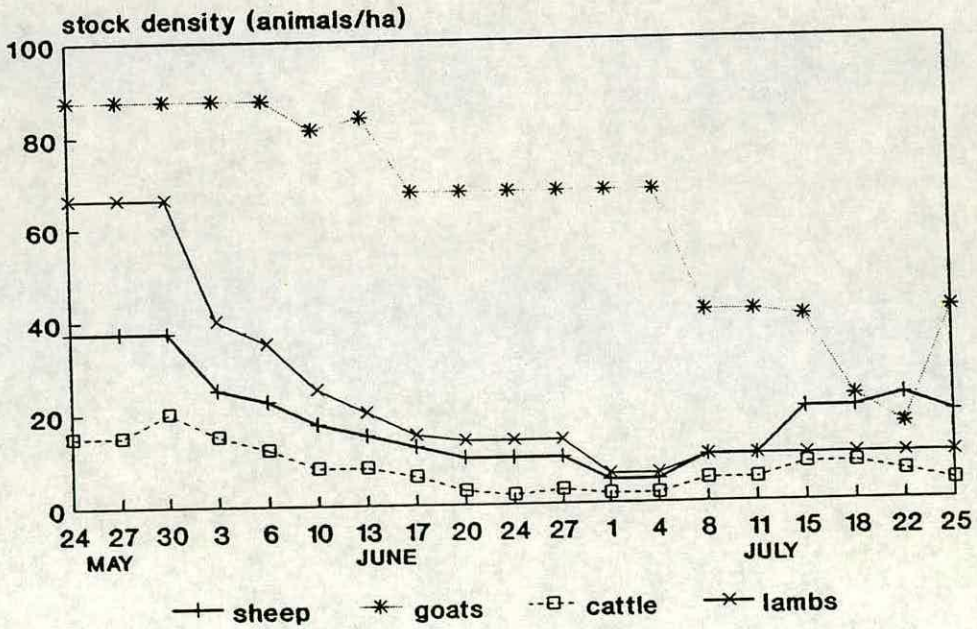


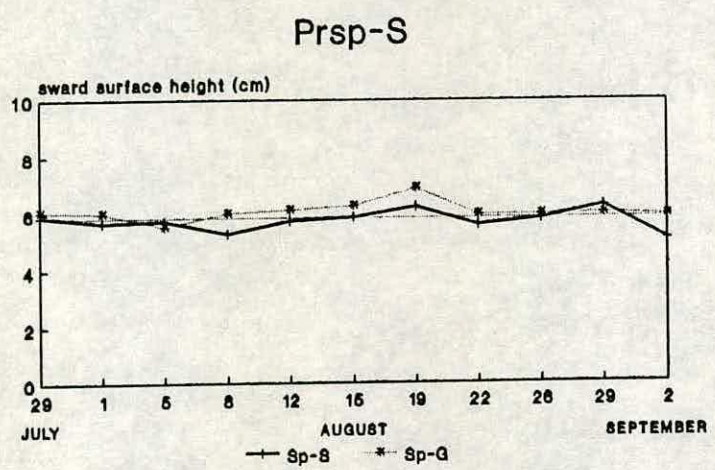
Figure 3.4. The pattern of change in a) sward surface heights and b) stocking density in Phase 1. Target sward height was 6.0 cm (...).

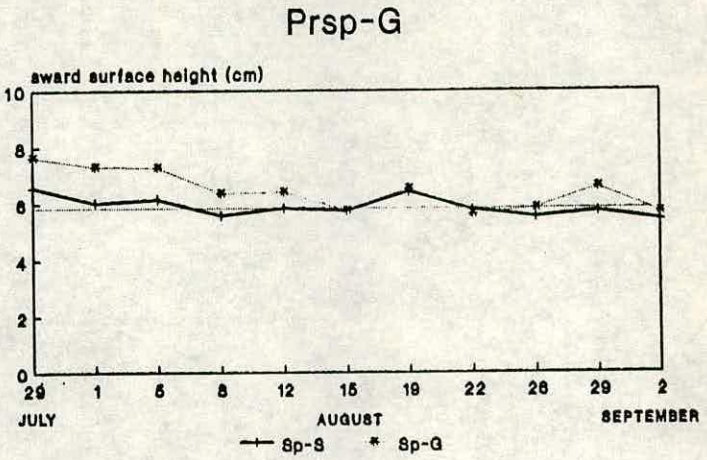
a)



b)







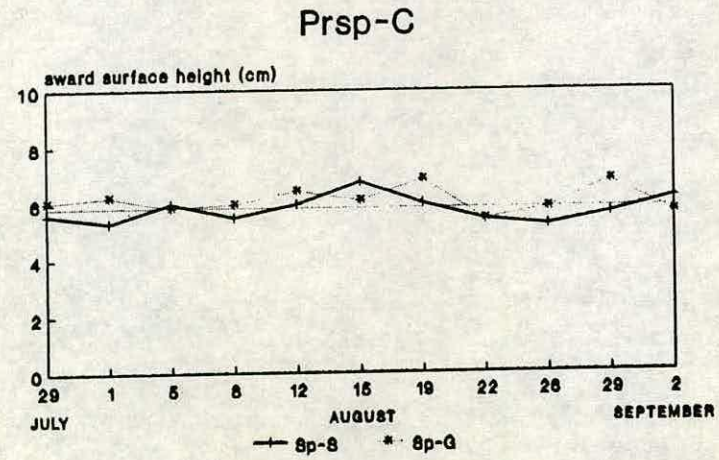


Figure 3.5. The pattern of change in sward surface heights in Phase 2 grouped by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Phase 1. Target sward height was 6.0 cm (...).

Table 3.2. Overall mean sward surface heights in Phase 1 (24 May- 25 July)[+] (n = 1900).

	Pre-species			
	sheep	goats	cattle	sed.
Sward height (cm)	5.93	6.37	6.34	0.331

[+]- Overall grand mean was 6.21 cm.

Table 3.3. Overall mean sward surface heights in Phase 2 (29 July - 2 September)(n = 1100).

	Pre-species						
	sheep		goat		cattle		
Species	sheep	goat	sheep	goat	sheep	goat	sed.
Sward Height (cm)	5.73	6.07	5.89	6.48	5.69	6.11	0.326[a] 0.422[b]

[a]- sed. of means with different pre-species level.

[b]- sed. of means with same pre-species level.

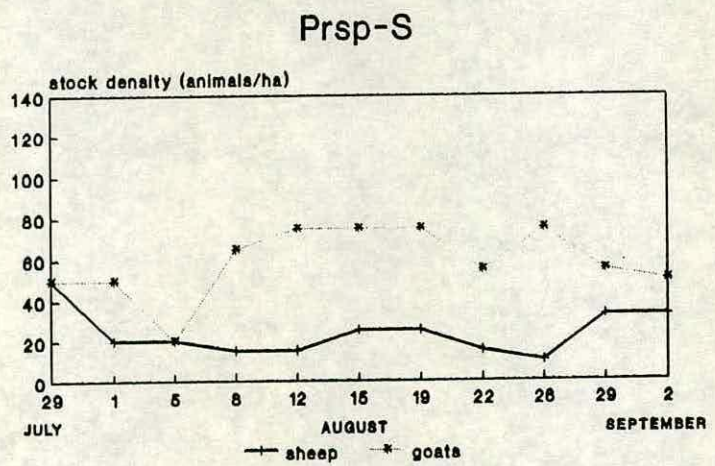
In Phase 2, the overall mean sward surface heights remained close to the target height of 6.0 cm and did not differ significantly between the three pre-species

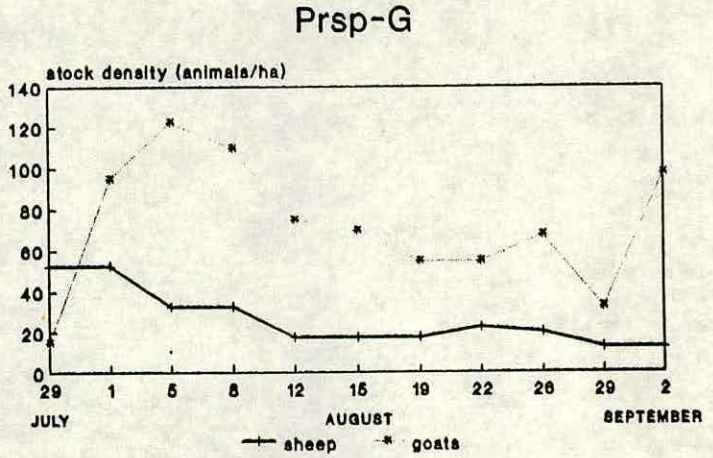
treatments (5.90, 6.18 and 5.90 cm for Prsp-S, Prsp-G and Prsp-C respectively; sed 0.331), or between species treatments (Sp-S and Sp-G: 5.77 and 6.22 cm respectively; sed 0.244).

Stocking densities in Phase 1 and Phase 2 are shown in Figure 3.4b) and in Figure 3.6 respectively. Similar patterns of stocking density occurred on all the pre-species treatments from the end of May to the middle of July. From 4 July the stocking density of sheep and cattle had to be increased to keep sward heights on target while the stocking density of goats continued to decrease. During Phase 2 there was a trend for higher stocking densities for goats and sheep to be required on the Prsp-G treatment than on Prsp-C and Prsp-S treatments (Figure 3.6). Mean stocking densities were 25.0, 24.0 and 19.5 sheep/ha on Prsp-G, Prsp-S and Prsp-C treatments respectively (sed. 3.74; ns) while 80.8, 63.5 and 60.2 goats/ha were used on Prsp-G, Prsp-S and Prsp-C treatments respectively (sed. 11.33; $p<0.1$).

3.4.2.1. Sward height patchiness.

The frequency distribution of the observed sward heights in Phase 1 and Phase 2 are shown in the histograms in Figures 3.7 and 3.8. Differences in the distributions of heights between treatments were compared using a Pearson's chi-square test (χ^2) to contrast the proportion of heights above 8 cm. The Prsp-C, Prsp-G and Prsp-S treatments had respectively 16.6%, 15.9% and 8.8% of 1900 heights recorded above 8 cm ($\chi^2=59.69$; df=2; $p<0.001$). This indicates that the paddocks grazed by cattle and goats had a more skewed distribution of sward heights with more tall areas.





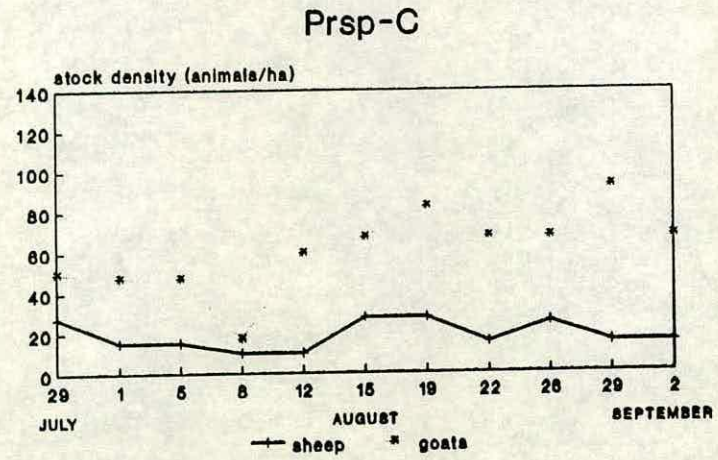
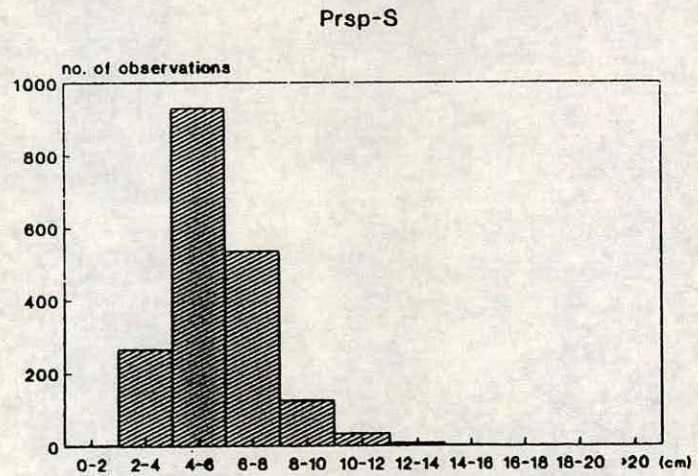
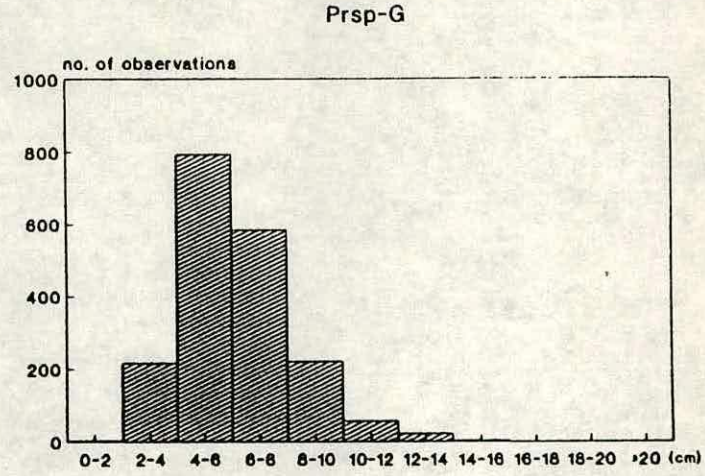


Figure 3.6. The pattern of change in stocking density of sheep and goats in Phase 2 grouped by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Phase 1. Target sward height was 6.0 cm.





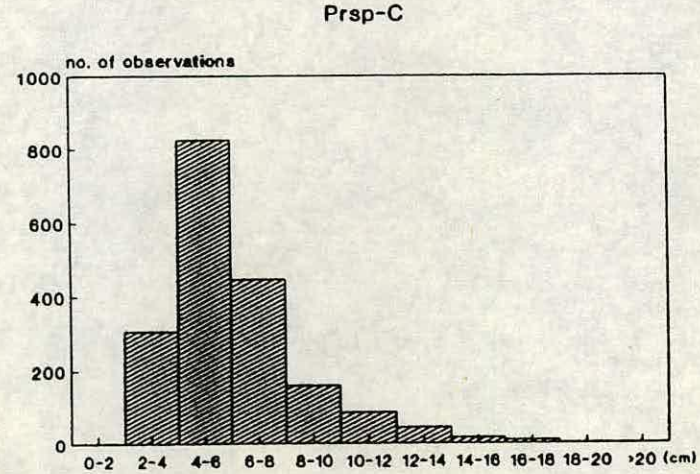
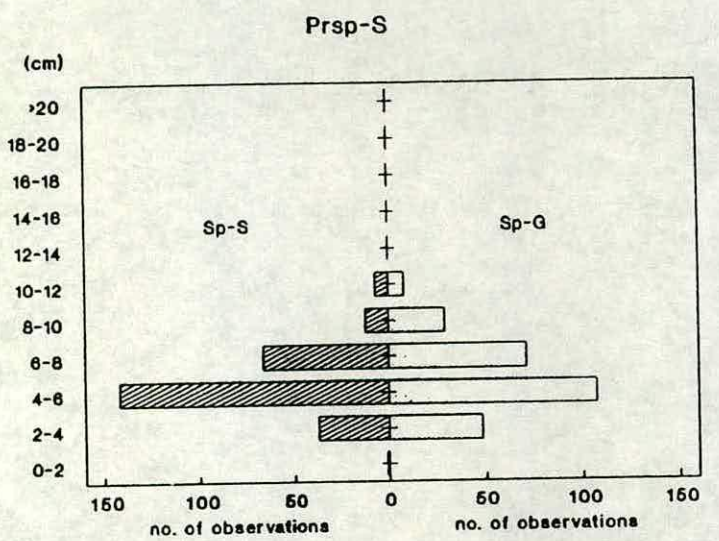
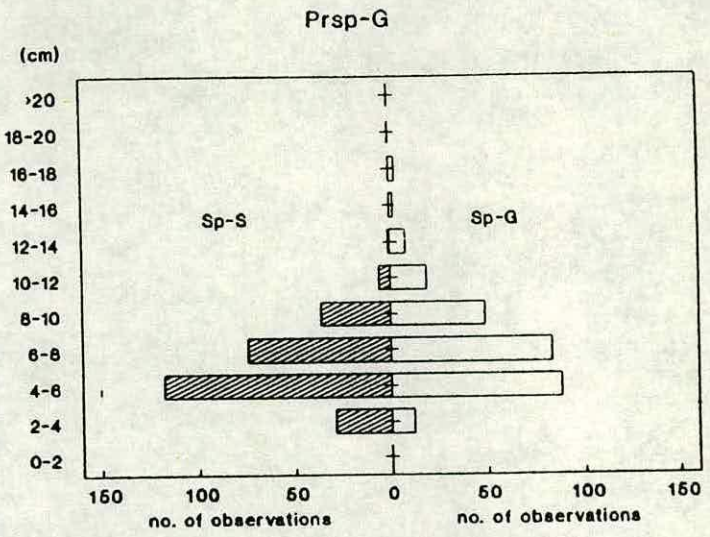


Figure 3.7. Frequency distribution of sward surface height measurements classified by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Phase 1. Measurements are grouped in 2 cm bands.





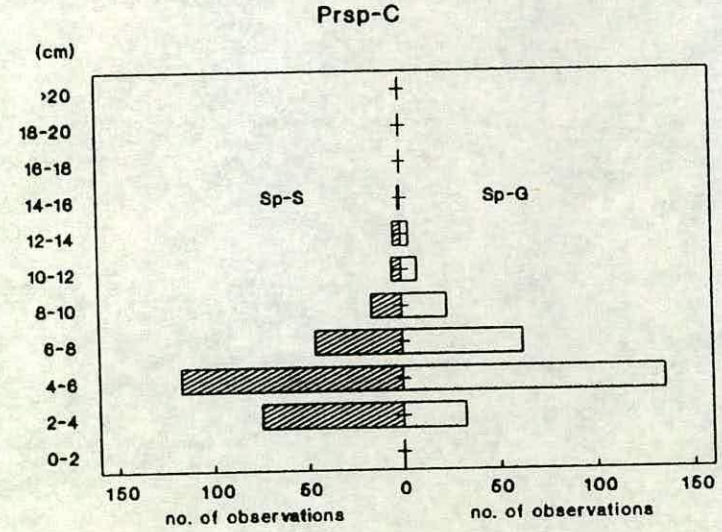


Figure 3.8. Frequency distributions of sward surface height measurements in Phase 2. Measurements are grouped in 2 cm bands and classified by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Phase 1 and by species: sheep (Sp-S) and goat (Sp-G) in Phase 2.

During Phase 2, the differences created by the effects of the pre-species in Phase 1 remained statistically significant with 11.7%, 14.4% and 9.8% of 2200 heights in the former cattle, goat and sheep treatments respectively, being above a height of 8 cm (χ^2=22.70; df=2; p<0.001). Animal species in Phase 2 (Sp-S or Sp-G) also affected the distribution of sward heights. Only 8.6% of 3300 sward heights were above 8 cm on plots grazed by sheep (Sp-S) in contrast to 15.4% on plots grazed by goats (Sp-G; χ^2=72.88; df=1; p<0.001) indicating a more even distribution of sward heights on sheep-grazed plots as in Phase 1.

The highest percentage (44.3%) of 1100 sward height measurements in Phase 2 above 8 cm was on the treatment grazed throughout the experiment by goats (treatment Prsp-G:Sp-G) while the lowest percentage (6.9%) was on the treatment grazed throughout by sheep (treatment Prsp-S:Sp-S).

The mean sward heights of the 24 quadrats used to measure sward composition were recorded and the quadrats divided into three categories (short, medium and tall) according to their heights. The mean heights in each of the three categories are summarised in Table 3.4 for Phase 1 (Period 1) and Table 3.5 for Phase 2 (Periods 2 and 3). In Period 1 overall mean heights were 3.16, 4.58 and 7.38 cm (sed. 0.220) for the short, medium and tall categories respectively. Although not statistically significant, there was a trend for the tall category to be higher on the Prsp-G and Prsp-C paddocks than on the Prsp-S paddocks and the short and medium categories tended to be higher on Prsp-G paddocks than in Prsp-S and Prsp-C paddocks, although the differences were not significant (see Table 3.4).

Table 3.4. Mean sward heights (cm) for short, medium and tall quadrats used to measure sward composition in Period 1. (n = 48)

	Pre-species			
	sheep	goats	cattle	sed
Sward height category				
Short	2.90[a]	3.51[a]	3.06[a]	0.547[+]
Medium	4.32[b]	5.06[b]	4.35[b]	0.381[++]
Tall	6.72[c]	7.71[c]	7.71[c]	

[a b c]- means within a column not sharing a common superscript differ significantly ($p<0.05$).

[+]- sed. of means with different pre-species level.

[++]- sed. of means with same pre-species level.

In Phase 2, the heights of the three sward height categories were 3.73, 5.00 and 6.76 cm (sed. 0.171) for short, medium and tall categories respectively (Table 3.5).

Table 3.5. Mean sward heights (cm) for short, medium and tall quadrats used to measure sward composition in Periods 2 and 3. Data are pooled across both periods (n = 96).

	Pre-species						
	sheep		goat		cattle		
Species	sheep	goat	sheep	goat	sheep	goat	sed.
Sward height category							
Short	3.93[a]	3.58[a]	3.90[a]	3.91[a]	3.73[a]	3.35[a]	0.505[+]
Medium	5.38[b]	5.03[b]	4.89[b]	5.13[b]	4.69[b]	4.85[b]	0.418[++]
Tall	7.18[c]	6.68[c]	6.40[c]	6.98[c]	6.56[c]	6.73[c]	

[a b c]- means within a column not sharing a common superscript differ significantly ($p<0.05$).

[+]- sed. of means with different pre-species x species level on the interaction pre-species x species x sward height category.

[++]- sed. of means with the same pre-species x species level on the interaction pre-species x species x sward height category.

3.4.3. Herbage mass.

Figure 3.9 shows mean herbage mass measured during the three sampling periods. There were no significant differences between pre-species treatments in Period 1 (at the end of Phase 1).

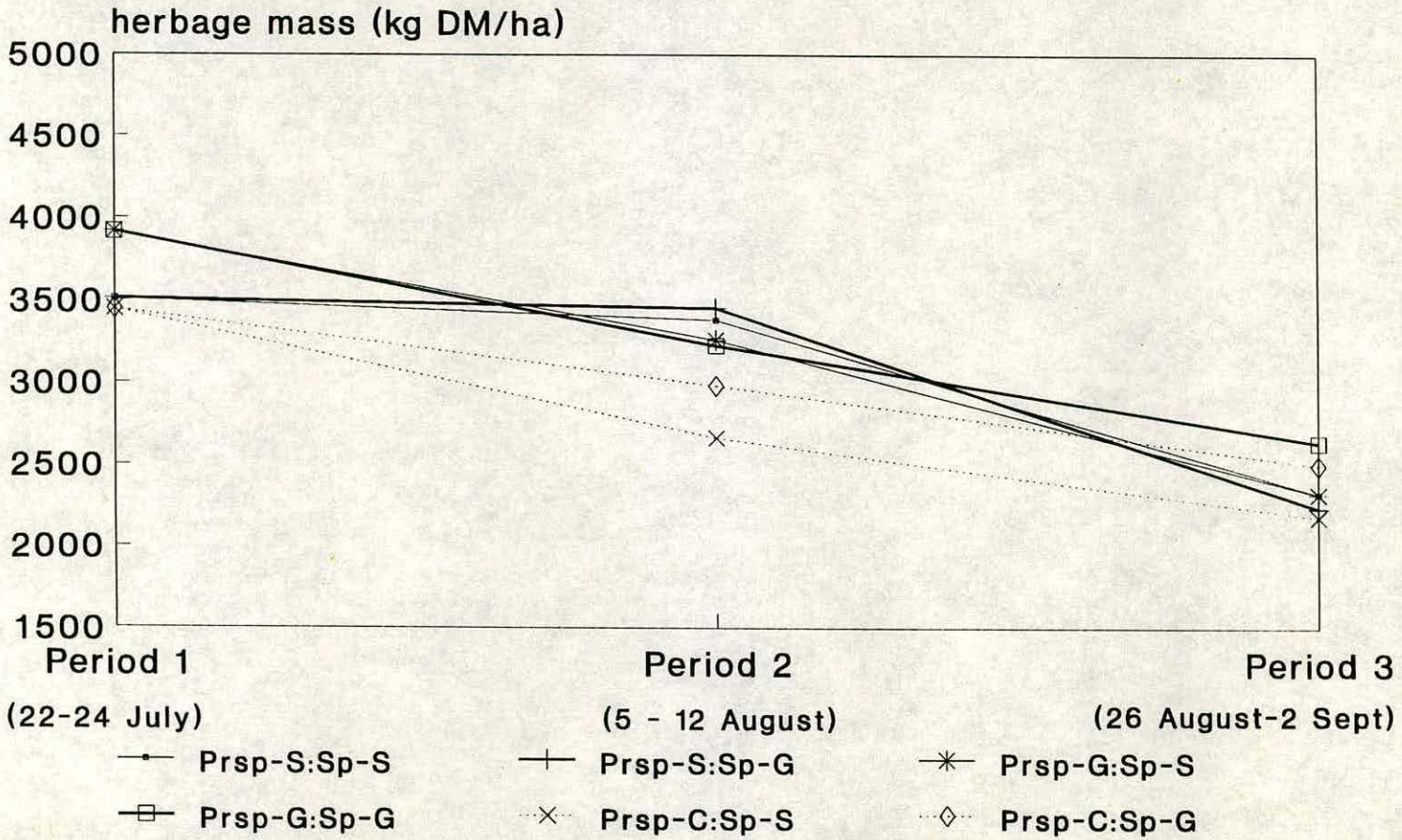
Herbage mass declined throughout Phase 2. Prsp-C treatment had lower herbage masses than Prsp-S and Prsp-G treatments in Period 2 ($p<0.05$) but not in Period 3.

As expected, tall height categories had higher herbage masses than medium and short height categories at all sampling Periods ($p<0.001$).

3.4.4. Sward composition.

The results of the sward composition measurements are presented separately for each Phase. The effects of treatment on overall sward composition is considered first, followed by the effects within sward height categories and then the effects within horizons. Also the treatment effects on the sward surface and the effects within sward surface height categories are presented for each Phase. Finally, differences between sampling periods are also mentioned where it is relevant.

Figure 3.9. Treatment herbage masses in Periods 1, 2 and 3.



3.4.4.1. Phase 1 (Period 1).

3.4.4.1.1. *Sward.*

Table 3.6 shows the percentages of total clover and total grass in the sward in Period 1 at the end of Phase 1, according to pre-species treatments. For this table and subsequent tables of the botanical composition (from Table 3.6 to Table 3.20) the number of observations were two per treatment (n = 2). Grass was by far the dominant species. Although there were no significant treatment effects, the Prsp-C treatment had a higher percentage of clover (11.8%) than the Prsp-S and Prsp-G treatments (9.5% and 8.8% respectively; sed. 2.51; ns). Figure 3.10 shows the percentage of the different botanical components according to the pre-species treatment. Live grass leaf was the largest component, followed by dead grass. Grass flowerstem was the smallest grass component. Clover lamina-petiole accounted for the majority of clover. The only significant differences due to pre-species treatment were that on the Prsp-G treatment there was less dead clover (0.2%) than on the Prsp-S (0.6%; $p<0.001$) or the Prsp-C (0.4%; sed. 0.06; $p<0.05$) treatments and less grass pseudostem on the goat-grazed paddocks than on the other paddocks (13.3% versus 17.9% and 15.4% for Prsp-G, Prsp-S and Prsp-C respectively; sed. 0.08; $p<0.001$).

The percentages of each botanical component in each sward height category according to pre-species treatment are shown in Table 3.7. There was no significant overall difference in percentage of total clover (11.8%-short, 10.0%-medium and 9.2%-tall; sed. 2.60) and total grass (85.9%-short, 87.6%-medium, 87.6%-tall; sed. 2.64) between sward height categories. Flower was the only clover component which differed between height categories with the highest percentage in the medium height category ($p<0.05$).

Table 3.6. Percentages of total grass and total clover dry matter components (live + dead) in the whole sward and on the sward surface classified by pre-species treatment in Period 1.

Component	Animal pre-species in Phase 1				
	sheep	goat	cattle	sed	p
SWARD					
Grass	87.9	87.3	86.5	3.26	ns
Clover	9.5	8.8	11.8	2.51	ns
SWARD-SURFACE					
Grass	86.9	80.4	79.4	8.72	ns
Clover	11.1	15.8	18.2	7.60	ns

Figure 3.10. Percentages of botanical components in the whole sward classified by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

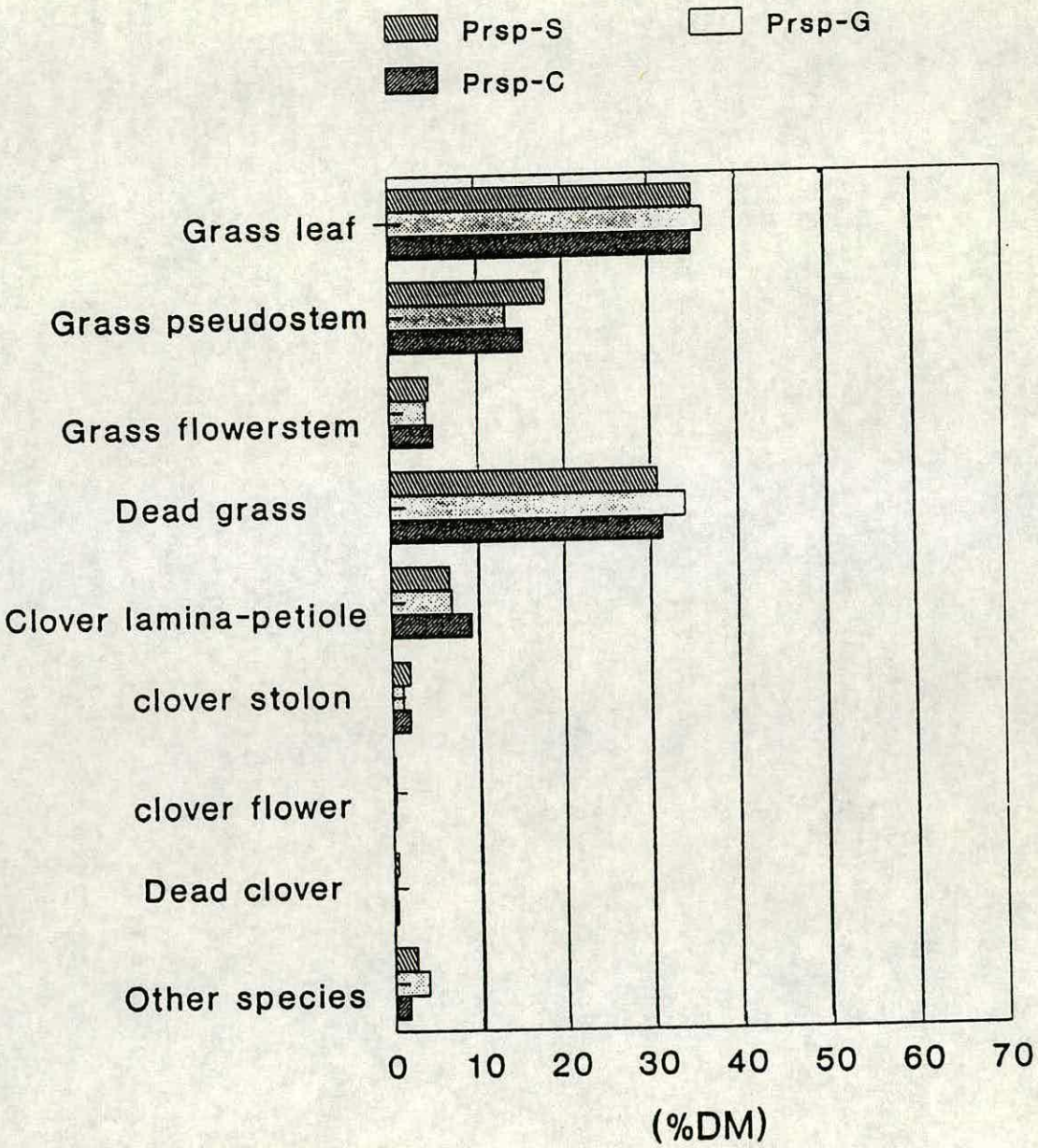


Table 3.7. Botanical components (%DM) in the whole sward classified by pre-species treatment and by sward height category in Period 1 at the end of Phase 1.

Component	Height Category (Sc)	Animal pre-species in Phase 1 (Prsp)			sed	Level of significance		
		Sheep	Goat	Cattle		Prsp	Sc	Prsp x Sc
Grass leaf	Short	34.3	37.7	28.3	6.54[a]/3.34[b]	ns	ns	ns
	Medium	32.1	34.1	36.2				
	Tall	36.8	36.5	37.7				
Grass pseudostem	Short	16.6	11.7	13.6	3.09[a]/3.65[b]	p=0.066	ns	ns
	Medium	16.0	12.4	16.4				
	Tall	19.5	14.9	15.9				
Grass flowerstem	Short	1.6	3.3	0.7	1.48[a]/1.70[b]	ns	*	ns
	Medium	5.3	2.1	5.4				
	Tall	5.6	6.4	7.0				
Dead grass	Short	35.8	36.5	38.0	4.94[a]/2.94[b]	ns	**	ns
	Medium	32.3	38.8	31.8				
	Tall	27.2	28.0	27.4				
Clover lamina-petiole	Short	6.7	7.3	13.3	3.63[a]/3.19[b]	ns	ns	ns
	Medium	8.8	6.0	6.6				
	Tall	5.4	7.6	8.4				
Clover stolon	Short	2.2	1.7	3.3	1.32[a]/1.31[b]	ns	ns	ns
	Medium	2.6	1.6	1.5				
	Tall	1.8	0.8	1.8				
Clover flower	Short	0.1	0.1	0.0	0.33[a]/0.35[b]	ns	*	ns
	Medium	0.9	0.6	0.6				
	Tall	0.0	0.2	0.1				
Dead clover	Short	0.2	0.0	0.4	0.22[a]/0.24[b]	ns	ns	ns
	Medium	0.4	0.1	0.4				
	Tall	0.7	0.4	0.3				
Other species	Short	2.7	1.6	2.5	1.61[a]/1.79[b]	ns	ns	ns
	Medium	1.7	4.3	1.2				
	Tall	3.0	5.2	1.5				

([a]- sed. of means with different pre-species level, [b]- sed. of means with same pre-species level)

For grass, only flowerstem and dead grass differed between height categories with the highest percentage of dead grass present in the short category ($p<0.01$) and the highest percentage of flowerstem in the tall category.

Prsp-C treatment had a higher percentage of clover than Prsp-S and Prsp-G treatments in the short category (17.0% versus 9.2% and 9.2% respectively; $p<0.05$) and tended to have more clover in the tall category (10.6% versus 7.9% and 9.0% respectively; ns) while in the medium category, the Prsp-S treatment had the highest percentage of clover (12.6%, 8.2% and 9.0% in the Prsp-S, Prsp-G and Prsp-C treatments respectively; overall sed. 2.60; ns). Since clover lamina-petiole accounted for a high percentage of total clover it followed a similar pattern.

In Period 1, there were very highly significant differences in the mass of all the botanical components between different horizons ($p<0.001$ in each case except $p<0.05$ for clover flower and dead clover; see Tables 3.8 and 3.9). The mass of both grass and clover (live plus dead material) was higher in the lower horizons: 2529, 387, 183 and 154 kg/ha (sed. 66.5) for grass and 248, 55, 40 and 29 kg/ha (sed. 20.1) for clover in the 0-2 cm, 2-4 cm, 4-6 cm and >6 cm horizons respectively ($p<0.001$).

The vertical distributions of the nine sward components for Period 1 are given graphically in Appendix 1 from Figure A1.1 to Figure A1.9 while the distribution of total grass and total clover components are described by Figures 3.11 and 3.12. Different vertical profiles of total grass ($p<0.05$), grass leaf ($p<0.05$), dead grass ($p=0.052$) and several clover components developed under different pre-species treatments.

Table 3.8. Botanical components (kg/ha/horizon) of the whole sward classified by pre-species treatment, by sward height category and by horizon in Period 1 at the end of Phase 1. Levels of significance are shown in Table 3.9.

Pre-species		Sheep			Goat			Cattle		
Height category		Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall
Component	Horizon (cm)									
Grass leaf	0-2	747	690	852	975	1028	783	640	741	749
	2-4	120	208	479	150	240	478	111	213	346
	4-6	17	94	280	25	100	294	12	82	330
	>6	4	30	232	3	24	250	2	24	419
Grass pseudostem	0-2	426	484	839	353	446	624	363	436	565
	2-4	7	11	80	5	73	101	6	33	92
	4-6	0	6	31	0	6	21	1	8	63
	>6	0	16	29	0	0	10	0	0	50
Grass flowerstem	0-2	39	114	165	81	59	227	11	141	206
	2-4	0	28	42	6	9	22	3	10	40
	4-6	1	6	36	14	2	18	2	3	44
	>6	0	17	38	0	13	48	2	7	56
Dead grass	0-2	931	952	1248	1111	1561	1217	1003	873	1077
	2-4	8	48	80	34	29	144	24	49	153
	4-6	2	14	7	2	17	29	2	11	65
	>6	1	15	31	3	11	17	0	2	34
Clover lamina-petiole	0-2	158	174	169	199	153	170	282	133	135
	2-4	9	58	54	42	53	66	63	34	57
	4-6	7	38	37	1	36	90	6	6	58
	>6	0	4	10	0	8	42	6	21	55
Clover stolon	0-2	56	76	86	58	56	16	83	25	75
	2-4	0	6	3	2	3	0	3	7	5
	4-6	0	0	0	0	8	0	1	2	7
	>6	0	0	0	0	0	0	0	9	2
Clover flower	0-2	2	3	2	1	7	7	0	16	3
	2-4	0	10	0	3	0	2	1	1	0
	4-6	0	12	0	0	20	3	0	0	0
	>6	0	0	0	0	0	0	0	0	0
Dead Clover	0-2	1	13	14	1	0	16	8	9	12
	2-4	4	0	4	0	2	0	3	2	3
	4-6	0	0	18	0	0	7	0	0	3
	>6	0	0	2	0	0	0	0	0	0
Other species	0-2	66	36	131	50	124	136	65	33	22
	2-4	0	20	6	3	25	81	4	1	9
	4-6	0	0	12	0	22	37	0	0	9
	>6	0	0	0	0	18	5	0	0	30

Table 3.9. Summary of the results of the analysis of variance of the effects of pre-species treatment (sheep, goats and cattle), sward height category (short, medium and tall), horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) and their interactions on the nine botanical components in Period 1 at the end of Phase 1.

	Grass leaf	Grass pseudostem	Grass flowerstem	Dead grass	Clover lamina-petiole	Clover stolon	Clover flower	Dead clover	Other species
Pre-species (Prsp)	ns	ns	ns	ns	ns	ns	ns	p=0.088	ns
Sward height category (Sc)	***	**	**	***	ns	ns	*	*	p=0.083
Horizon (H)	***	***	***	***	***	***	.	.	***
(Prsp x Sc)	ns	ns	ns	**	ns	ns	ns	ns	ns
(Sc x H)	***	**	***	ns	*	ns	p=0.058	ns	ns
(Prsp x H)	*	ns	ns	p=0.052	ns	ns	p=0.099	ns	ns
(Prsp x Sc x H)	ns	ns	ns	ns	ns	ns	*	ns	ns

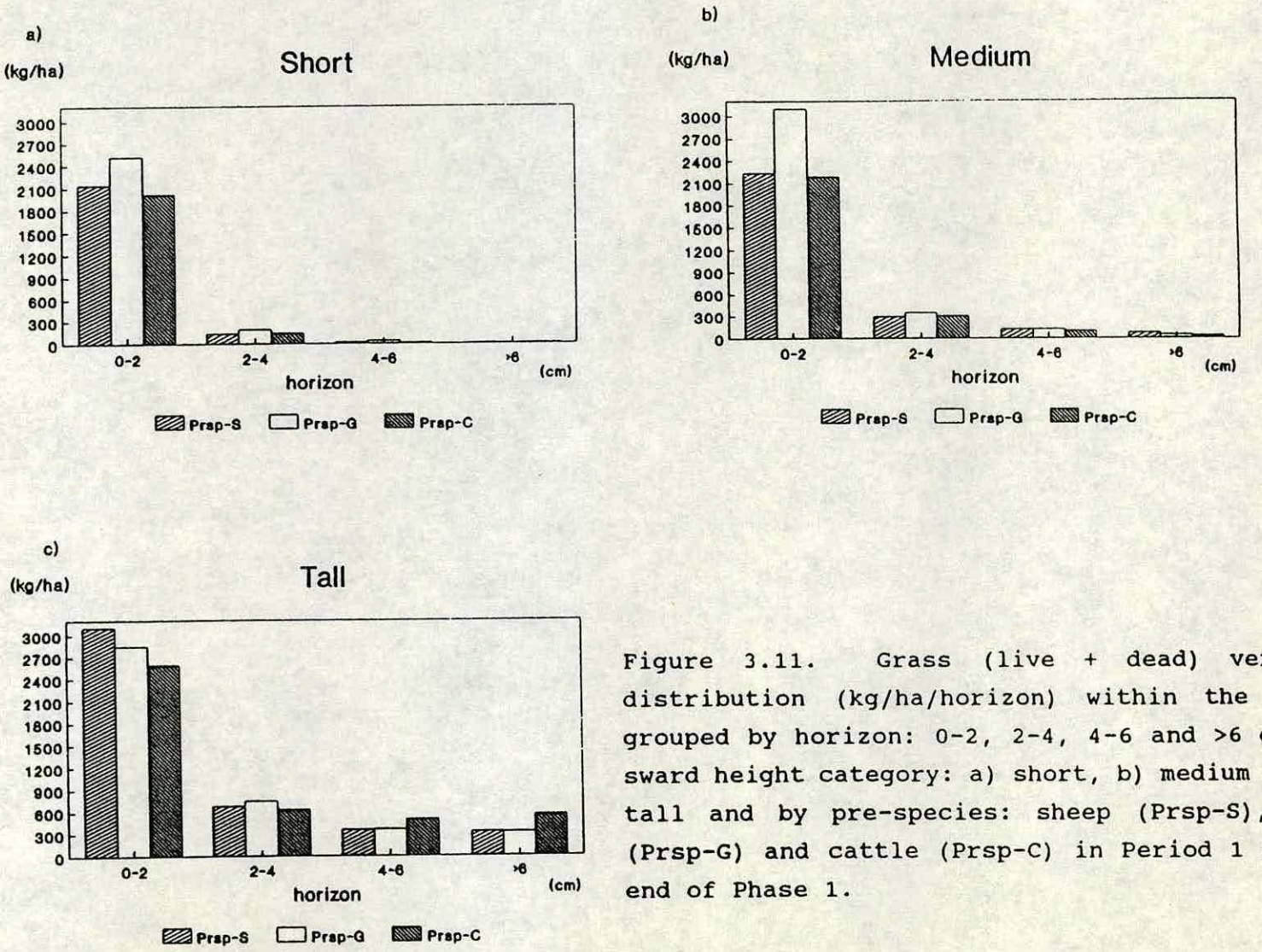


Figure 3.11. Grass (live + dead) vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

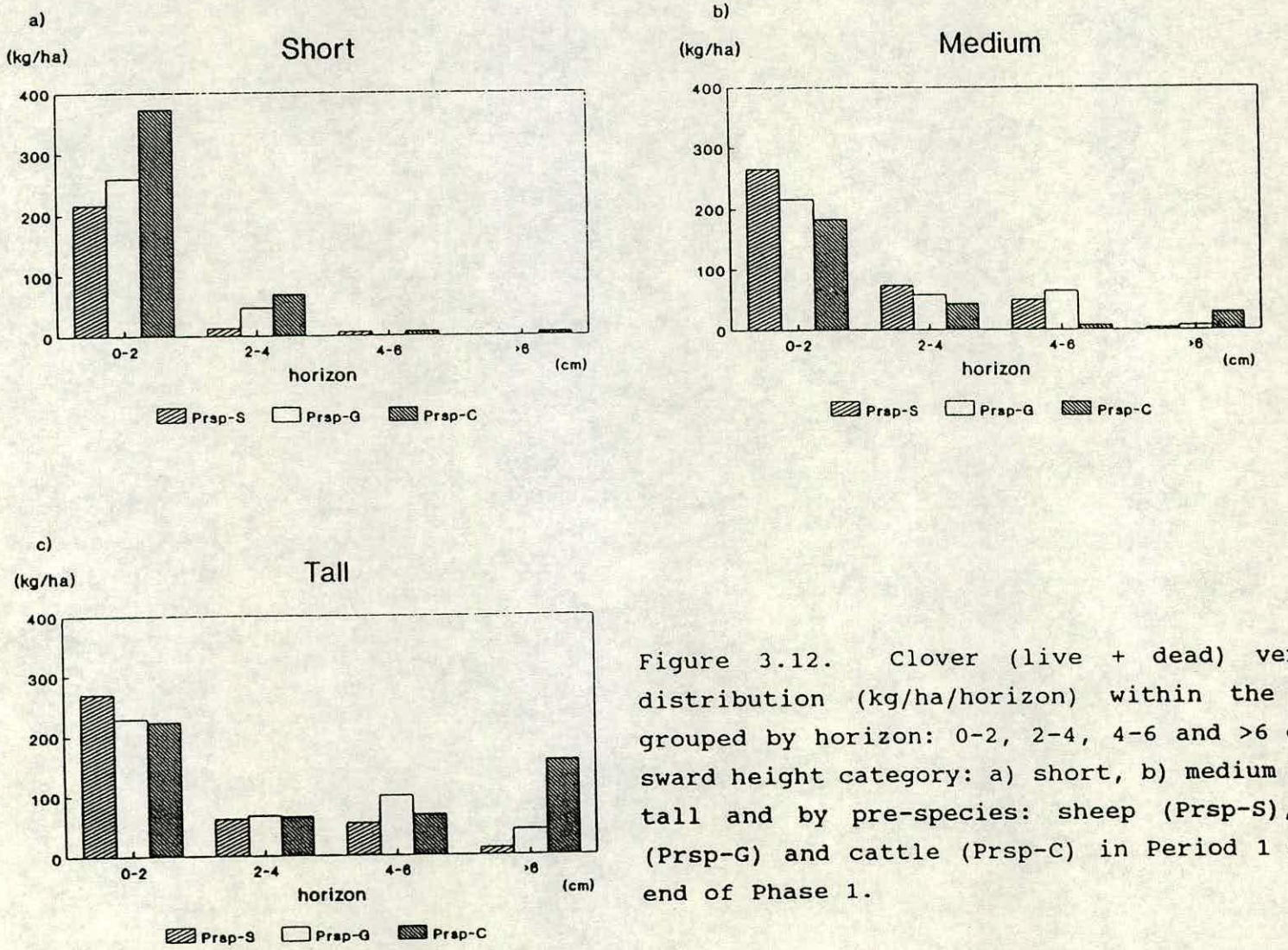


Figure 3.12. Clover (live + dead) vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

On the Prsp-G treatment in the basal horizon (0-2 cm horizon) there were higher amounts of total grass (2822 versus 2495 and 2269 kg/ha for Prsp-G, Prsp-S and Prsp-C respectively; sed. 137.9; $p<0.05$) and of grass leaf (929 versus 747 and 852 kg/ha respectively; sed. 49.5; $p<0.05$).

Amounts of grass flowerstems in each horizon were similar between pre-species treatments but grass pseudostem was less abundant in upper horizons (4-6 cm and >6 cm) on the Prsp-G treatment (8.8 and 3.2 kg/ha respectively) than on the other pre-species treatments (12.5 and 14.9 kg/ha on Prsp-S and 24.0 and 16.6 kg/ha on Prsp-C treatments in the 4-6 cm and >6 cm horizons respectively)(overall sed. 40.44). Dead grass tended to be more abundant in the lowest horizon (0-2 cm horizon) of Prsp-G paddocks (1297.0 kg/ha) than on Prsp-C (985.0 kg/ha; $p<0.1$) and on Prsp-S paddocks (1043.0 kg/ha; sed. 103.00; ns). In contrast to grass, all the pre-species treatments had similar amounts of total clover and clover lamina-petiole in all horizons. There was more clover flower ($p<0.001$) in the 4-6 cm horizon on Prsp-G paddocks (7.7 kg/ha) than on Prsp-C (0.0 kg/ha) and Prsp-S paddocks (3.9 kg/ha; sed. 2.34; $p<0.1$) with no clover in the >6 cm horizon.

Short sward height categories had more clover and less grass in the 0-2 cm horizon compared to medium and short height categories. As might be expected there was more clover (74 and 71 kg/ha) and more grass (406 and 404 kg/ha) in the upper horizons of the sward (4-6 cm and >6 cm respectively) on the tall sward height category compared to the short (5 and 2 kg/ha of clover and 26 and 5 kg/ha of grass) and medium categories (41 and 14 kg/ha of clover and 116 and 53 kg/ha of grass; overall sed. 41.7 and 137.9 respectively).

Furthermore, tall sward height categories had greater amounts in all horizons than short and medium categories of grass pseudostem ($p<0.01$), grass flowerstem ($p<0.001$), dead grass (ns), clover lamina-petiole ($p<0.05$), dead clover (ns) and other species (ns) and also there was more grass leaf in the 2-4 cm, 4-6 cm and >6 cm horizons on taller categories ($p<0.001$).

3.4.4.1.2. *Sward surface.*

Although there was a trend towards a higher percentage of total clover on the surface of the Prsp-C treatment (18.2%) compared to Prsp-G (15.8%) and to Prsp-S treatments (11.1%; sed. 7.60; ns), the differences were not significant (see Table 3.6). The only botanical component to show a significant effect of pre-species was clover flower where the Prsp-G paddocks had a higher percentage of clover over the surface of the sward ($p<0.05$).

Data on the percentage of the botanical components on the sward surface of each sward height category for each pre-species treatment are displayed in Table 3.10. There was no effect of pre-species on any botanical component on the surface of the short, medium or tall areas, nor was there a pre-species x sward height category interaction. Taller sward height categories had higher percentages of grass leaf ($p<0.01$) and grass flowerstem ($p<0.001$) but less dead grass ($p<0.01$) on the sward surface. Clover flower was the only clover component which was affected by height category, with more clover flower on the surface of the medium than on the short and tall categories ($p<0.01$).

Table 3.10. Botanical components (%DM) on the sward surface classified by pre-species treatment and by sward height category in Period 1.

Component	Height Category (Sc)	Animal pre-species in Phase 1 (Prsp)			sed	Level of significance		
		Sheep	Goat	Cattle		Prsp	Sc	Prsp x Sc
Grass leaf	Short	39.1	53.2	37.4	8.41[a]/6.77[b]	ns	**	ns
	Medium	47.5	51.1	63.7				
	Tall	65.9	65.1	56.4				
Grass pseudostem	Short	15.2	4.8	9.2	5.13[a]/5.65[b]	ns	ns	ns
	Medium	5.6	7.8	8.9				
	Tall	8.2	3.5	8.0				
Grass flowerstem	Short	1.3	2.7	0.9	1.93[a]/1.81[b]	ns	***	ns
	Medium	7.2	2.0	2.9				
	Tall	9.9	11.6	7.6				
Dead grass	Short	32.8	19.3	25.5	6.66[a]/5.92[b]	ns	**	ns
	Medium	15.3	8.1	12.7				
	Tall	6.1	5.4	6.8				
Clover lamina-petiole	Short	6.7	16.9	21.6	9.61[a]/8.06[b]	ns	ns	ns
	Medium	15.4	15.0	9.0				
	Tall	6.1	11.7	17.2				
Clover stolon	Short	2.0	0.8	2.4	1.39[a]/1.58[b]	ns	ns	ns
	Medium	1.4	2.1	2.1				
	Tall	0.1	0.0	0.6				
Clover flower	Short	0.1	0.9	0.1	1.83[a]/1.89[b]	ns	*	ns
	Medium	4.2	5.6	0.3				
	Tall	0.0	0.1	0.0				
Dead clover	Short	0.6	0.0	0.7	0.95[a]/0.85[b]	ns	ns	ns
	Medium	0.1	0.2	0.3				
	Tall	2.1	0.2	0.2				
Other species	Short	2.3	1.3	2.1	3.88[a]/3.87[b]	ns	ns	ns
	Medium	3.3	8.0	0.1				
	Tall	1.6	2.3	3.2				

([a]- sed.of means with different pre-species level, [b]- sed. of means with same pre-species level).

3.4.4.2. Phase 2 (Periods 2 and 3).

3.4.4.2.1. *Sward.*

The mean percentages of grass and clover in the whole sward according to pre-species and species treatment are given in Table 3.11 while Figures 3.13 and 3.14 show the distribution of the percentages of each botanical component classified by pre-species x species treatment for Periods 2 and 3 respectively. During Phase 2 larger overall increases in the percentage of clover tended to occur on Prsp-C and on Prsp-G treatments (+11.0% and +7.8%) than on Prsp-S treatment (+4.8%; sed. 3.69; ns). This trend was especially marked between Periods 2 and 3: +9.7%, +6.7% and +1.6% for Prsp-C, Prsp-G and Prsp-S treatments respectively (sed. 6.27; ns). As a consequence there was a tendency for the percentage of clover on the Prsp-C treatment to be higher than on the Prsp-S and Prsp-G treatments: 12.6%, 9.9% and 13.2% in Period 2 (sed. 2.72) and 22.9%, 14.3% and 16.5% in Period 3 for Prsp-C, Prsp-S and Prsp-G treatments respectively (sed. 3.81). Furthermore there was a tendency for larger increases in percentage of clover lamina-petiole to occur on Prsp-C and on Prsp-G treatments particularly between Periods 2 and 3 (see Figures 3.13 and 3.14). Therefore, Prsp-C plots tended to have higher percentages of clover lamina-petiole in both sampling periods. Dead clover increased on Prsp-G and on Prsp-C treatments and decreased significantly on Prsp-S treatments between Periods 1 and 2 ($p<0.001$). Also, in Period 2, Prsp-S plots had more clover stolon ($p<0.1$) than Prsp-C and Prsp-G plots but not in Period 3.

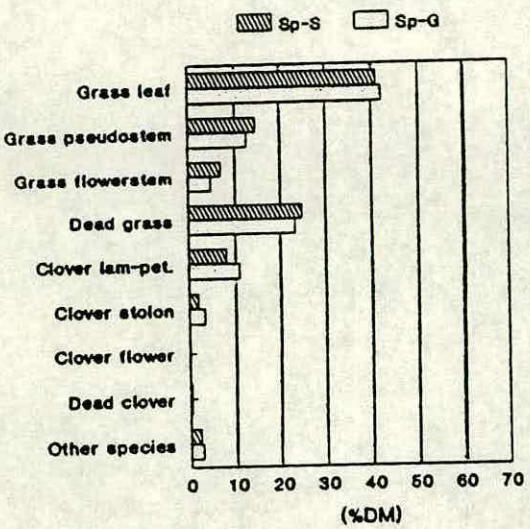
Table 3.11. Percentages of total grass and total clover dry matter components (live + dead) in the whole sward classified by pre-species treatment and by species treatment in Periods 2 and 3 in Phase 2.

	Pre-species (Prsp)	sheep		goat		cattle			Level of significance		
	Species (Sp)	sheep	goat	sheep	goat	sheep	goat	sed	Prsp	Sp	Prsp x Sp
	Period										
Grass	2	87.2	82.6	91.7	81.8	84.7	85.9	3.35[a] / 3.51[b]	ns	ns	ns
	3	86.5	79.8	85.5	75.8	79.3	70.8	6.87[a] / 7.71[b]	ns	ns	ns
Clover	2	10.6	14.7	5.3	14.4	13.8	12.6	3.25[a] / 2.50[b]	ns	p=0.070	ns
	3	11.3	17.3	12.1	20.9	18.2	27.5	6.58[a] / 7.59[b]	ns	ns	ns

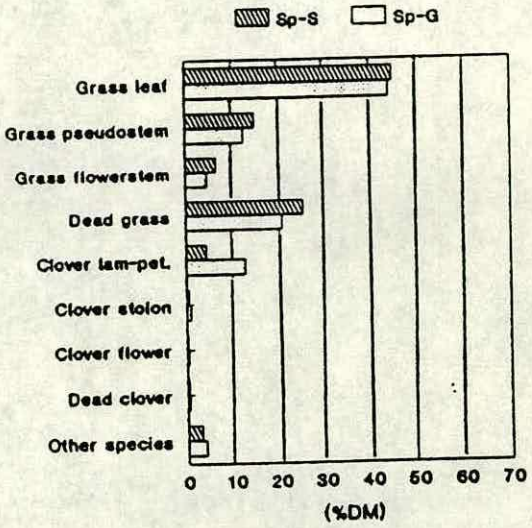
([a]- sed. of means with different pre-species level [b]- sed. of means with same pre-species level)

Figure 3.13. Percentages of botanical components in the whole sward grouped by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) and by species: sheep (Sp-S) and goat (Sp-G) in Period 2 in Phase 2.

a) Prsp-S



b) Prsp-G



c) Prsp-C

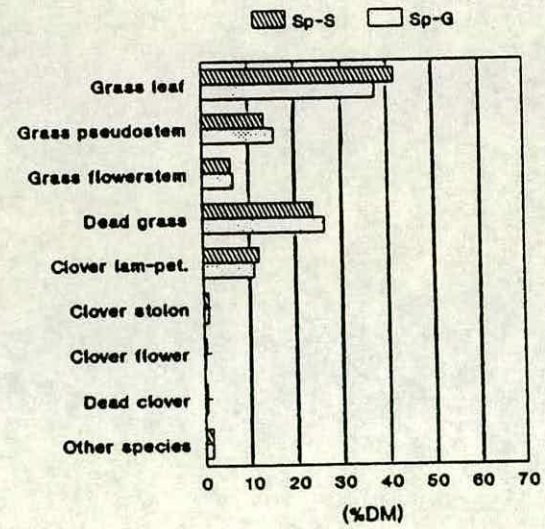
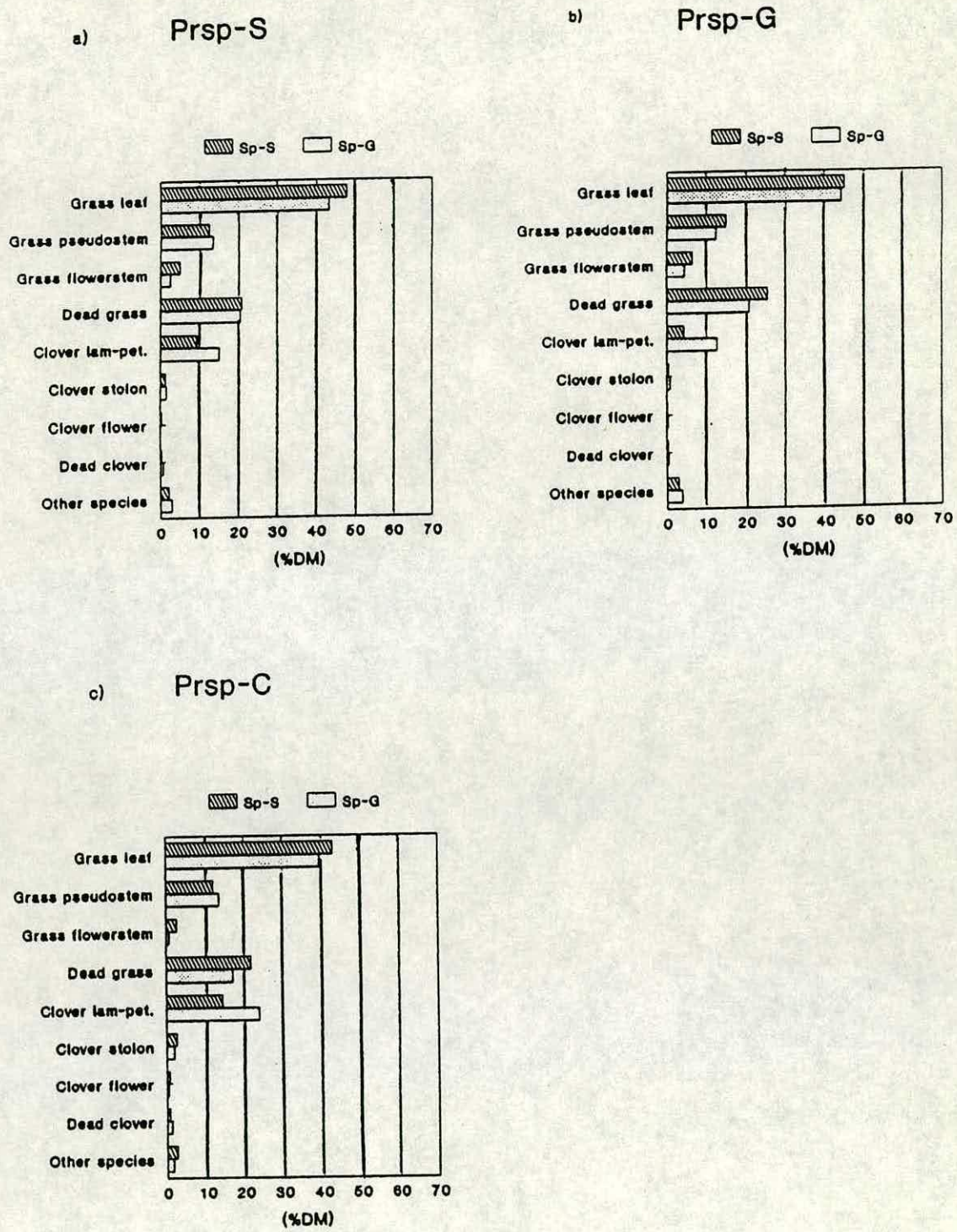


Figure 3.14. Percentages of botanical components in the whole sward grouped by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) and by species: sheep (Sp-S) and goat (Sp-G) in Period 3 at the end of Phase 2.



In contrast to clover, a decrease in the percentage of grass occurred during Phase 2: 84.9%, 86.7% and 85.3% grass (sed. 2.25; ns) in Period 2 and 83.2%, 80.6% and 75.0% grass (sed. 4.19; ns) in Period 3 were present on Prsp-S, Prsp-G and Prsp-C treatments respectively. The percentage of dead grass was higher on Prsp-C and Prsp-S plots than on Prsp-G plots ($p<0.1$) although the Prsp-G treatment had higher dead grass masses in the 0-2 cm horizon through both sampling periods.

Grazing by goats in Phase 2 (the Sp-G treatment) increased the percentage of clover to a greater extent than grazing by sheep (the Sp-S treatment): +11.9% versus +3.8% from Period 1 for Sp-G and Sp-S treatments respectively (sed. 4.38). This was already noticeable between Periods 1 and 2: +3.9% versus -0.1% for Sp-G and Sp-S respectively; sed. 2.03) leading to overall percentages of clover on Sp-G and on Sp-S plots of 13.9% versus 9.9% (sed. 1.44; $p<0.1$) in Period 2 and 21.9% versus 13.9% (sed. 4.38; ns) in Period 3. Also from Period 1 to Period 2, the Sp-G treatment had greater increases in percentages of clover lamina-petiole than the Sp-S treatment ($p<0.05$) so that during Phase 2, Sp-G treatments had higher percentages of clover lamina-petiole ($p<0.05$ for both periods; see Figures 3.13 and 3.14). Also Sp-G treatment had greater percentages of dead clover by the end of Phase 2, in Period 3 ($p<0.05$). The effects on grass components were the opposite to these on clover. In comparison with Sp-S treatment, Sp-G treatment displayed lower percentages of grass: 83.4% versus 87.9% (sed. 2.03; ns) in Period 2 and 83.8% versus 75.4% (sed 4.45; ns) in Period 3. These trends were reflected in the lower percentages of grass leaf (44.7% versus 41.3% for Sp-S and Sp-G treatments respectively; sed 2.10; $p<0.1$ in Period 3) and of dead grass ($p<0.1$ for both periods) present on Sp-G plots. Also there was less of a decline in the percentage of grass

flowerstem on Sp-S treatment than on Sp-G treatment from Period 1 to Period 3.

During Phase 2, the Sp-G plots had a larger increase than the Sp-S plots in the percentage of clover from Period 1 either on Prsp-S (+7.8% versus +1.8%), on Prsp-G (+12.2% versus +3.3%) and on Prsp-C treatments (+15.7% versus +6.4%) (overall sed. 4.38). Especially marked on Prsp-G plots between Periods 1 and 2 was the increase in clover content when they were grazed by goats (+5.6%) and the decrease in clover when grazed by sheep (-3.4%; sed. 5.30). Consequently, although the differences did not quite reach statistical significance, there were higher percentages of clover in Period 2 on the Prsp-S treatment for the Sp-G treatment than on Sp-S treatment (14.7% versus 10.6%) and also on the Prsp-G treatment (14.4% versus 5.3%) but not on the Prsp-C treatment (12.6% versus 13.8%)(overall sed. 3.25). In Period 3 there was also a higher percentage of clover for the Sp-G than for the Sp-S treatment on the Prsp-S treatment (17.3% versus 11.3%), on the Prsp-G treatment (20.9% versus 12.1%) and on the Prsp-C treatment (27.5% versus 18.2%)(overall sed. 6.58). Percentages of clover lamina-petiole followed a similar distribution and differences were statistically different ($p<0.05$) in Period 2 (see Table 3.12). Although present in low percentages, clover flower was higher for the Sp-G treatment than for the Sp-S treatment on the Prsp-G treatment in both sampling periods ($p<0.05$) but lower on the Prsp-C treatment ($p<0.05$; see Tables 3.12 and 3.13). This was due to an increase on the Prsp-C:Sp-S treatment between Periods 2 and 3 ($p<0.05$).

Tables 3.12 and 3.13 show the percentage of each botanical component in Periods 2 and 3 respectively classified by pre-species, species and sward height category.

Table 3.12. Botanical components (% DM) in the whole sward classified by pre-species treatment, by species treatment and by sward height category in Period 2.

Pre-species (Prsp)		sheep		goat		cattle			Level of significance
Species (Sp)		sheep	goat	sheep	goat	sheep	goat	sed	
Component	Height Category (Sc)								
Grass leaf	Short	39.8	43.1	44.7	44.7	43.0	37.1		
	Medium	47.2	41.0	48.7	41.2	42.4	40.7	4.96*	
	Tall	38.3	42.2	42.2	46.2	39.7	36.1		
Grass pseudostem	Short	11.7	10.7	14.1	11.9	10.3	11.4		
	Medium	13.1	12.7	12.7	13.6	15.0	15.6	2.44*	Sc *
	Tall	17.2	13.5	16.7	11.5	13.7	17.4		
Grass flowerstem	Short	4.0	4.1	6.5	4.4	5.6	5.0		
	Medium	4.9	4.7	4.3	4.2	6.0	4.9	2.31*	Sc *
	Tall	9.5	5.2	8.0	4.9	6.3	8.6		
Dead grass	Short	31.1	25.6	26.7	25.0	23.1	24.2		
	Medium	21.7	20.9	26.1	20.2	25.5	24.8	4.41*	
	Tall	23.2	23.5	24.5	18.7	23.1	28.5		
Clover lamina-petiole	Short	7.7	12.9	4.0	9.6	14.0	17.2		Sp *,
	Medium	8.9	13.8	4.4	14.1	8.3	11.4	3.60*	Prsp x Sp *,
	Tall	7.7	8.2	4.7	13.3	13.6	7.1		Prsp x Sc *
Clover stolon	Short	1.9	1.9	0.8	0.5	1.3	2.1		
	Medium	2.3	1.8	0.4	1.7	1.0	0.9	1.53*	
	Tall	1.6	5.1	0.4	0.3	0.8	0.4		
Clover flower	Short	0.1	0.1	0.4	1.0	0.3	0.2		
	Medium	0.1	0.1	0.2	0.1	0.6	0.1	0.28*	
	Tall	0.1	0.2	0.1	0.3	0.5	0.3		
Dead clover	Short	0.3	0.3	0.1	0.5	0.4	1.0		
	Medium	0.1	0.5	0.4	0.6	0.6	0.5	0.18*	Sp x Sc (p=0.051)
	Tall	0.5	0.2	0.3	0.5	0.5	0.3		
Other species	Short	3.6	1.4	2.7	2.4	2.0	1.9		
	Medium	1.7	4.6	2.8	4.3	0.6	1.2	2.07*	
	Tall	1.9	2.1	3.1	4.4	1.9	1.3		

(*- sed. of means of the interaction Prsp x Sp x Sc).

Table 3.13. Botanical components (% DM) in the whole sward classified by pre-species treatment, by species treatment and by sward height category in Period 3 at the end of Phase 2.

Pre-species (Prsp)		sheep		goat		cattle			Level of significance
Species (Sp)		sheep	goat	sheep	goat	sheep	goat	sed	
Component	**Height Category (Sc)**								
Grass leaf	Short	46.7	41.9	42.9	40.6	46.6	38.4		
	Medium	46.7	42.3	45.8	39.9	44.7	38.6	4.20*	
	Tall	49.4	45.1	41.7	42.2	38.7	40.5		
Grass pseudostem	Short	10.2	12.7	9.9	12.3	10.0	14.2		
	Medium	11.8	12.8	13.5	12.0	13.1	12.7	4.20*	
	Tall	14.1	14.5	14.5	14.9	12.4	13.5		
Grass flowerstem	Short	3.4	2.2	5.6	3.4	4.4	2.1		
	Medium	5.0	2.9	1.1	1.7	1.3	0.0	1.89*	
	Tall	6.3	2.2	5.5	2.5	2.9	0.6		
Dead grass	Short	21.5	18.6	18.6	21.6	19.5	16.6		
	Medium	19.8	20.9	27.5	16.1	24.5	18.6	2.46*	Sp (p=0.067),
	Tall	21.7	21.7	26.7	19.4	21.0	16.2		Prsp x Sp x Sc *
Clover lamina-petiole	Short	13.9	14.8	15.6	17.4	13.8	23.9		
	Medium	10.6	18.6	9.9	22.9	12.0	24.7	6.92*	
	Tall	5.7	11.7	8.0	17.1	16.4	23.3		
Clover stolon	Short	1.5	2.1	2.9	0.7	2.5	2.8		Sc *
	Medium	2.0	1.2	1.0	1.2	3.0	1.9	0.88*	
	Tall	0.6	1.4	0.9	0.8	2.0	1.4		
Clover flower	Short	0.6	0.1	0.0	0.2	0.0	0.1		
	Medium	0.0	0.0	0.0	1.2	0.3	0.5	0.73*	
	Tall	0.4	0.0	0.2	0.0	1.7	0.8		
Dead clover	Short	0.2	1.1	0.3	0.6	0.6	0.4		
	Medium	0.6	1.0	0.1	0.6	0.3	1.4	0.54*	Sp *
	Tall	0.2	0.4	0.2	0.8	1.1	1.8		
Other species	Short	1.9	6.6	4.3	3.2	2.6	1.5		
	Medium	3.4	0.3	1.1	4.5	0.9	1.7	1.35*	Prsp x Sp x Sc *
	Tall	1.5	3.0	2.3	2.2	3.7	1.9		

(* - sed. of means of the interaction Prsp x Sp x Sc).

Furthermore, Figures 3.15, 3.16 and 3.17 respectively display graphically for Prsp-S, Prsp-G and Prsp-C treatments the percentages of grass, clover and other components for each species treatment (Sp-G or Sp-S) in each sward height category. For comparison, the results for Period 1 are also shown.

Overall, short and medium categories tended to have higher percentages of clover (13.1% and 12.1% in Period 2 and 19.3% and 19.2% in Period 3) than tall categories (11.1% in Period 2; sed. 1.40 and 16.2% in Period 3; sed. 2.17) although the difference was not significant. Between Periods 1 and 3 there was an increase in the clover percentage on all height categories (+7.5%, +9.2% and +7.0% for short, medium and tall categories respectively; sed. 2.37) and also of clover lamina-petiole (ns). Percentages of clover flower decreased on the medium category but increased on the tall category ($p<0.05$). Grass percentages of 84.6%, 85.4% and 86.4% in Period 2 (sed. 1.23%; ns) and 77.4%, 78.9% and 81.42% in Period 3 (sed. 2.28; ns) were present on short, medium and tall categories respectively. Percentages of grass pseudostem and grass flowerstems were higher on tall categories ($p<0.05$ respectively for both sampling periods). Although the short height category had higher percentages of dead grass than on the medium ($p<0.05$) and tall categories ($p<0.1$) in Period 2, the percentage of dead grass decreased dramatically between Periods 1 and 3 on the short category (-17.3%) in contrast to an increase in the medium (+13.1%) and tall categories (+6.4%; sed. 1.59; $p<0.001$).

Figure 3.15. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species in the whole sward divided into three sward height categories: short (S), medium (M) and tall (T) grazed either by sheep (Sp-S) or goats (Sp-G) in Phase 2 (Periods 2 and 3) after have been grazed by sheep (Prsp-S) in Phase 1. For comparison, the data from Period 1 is also given.

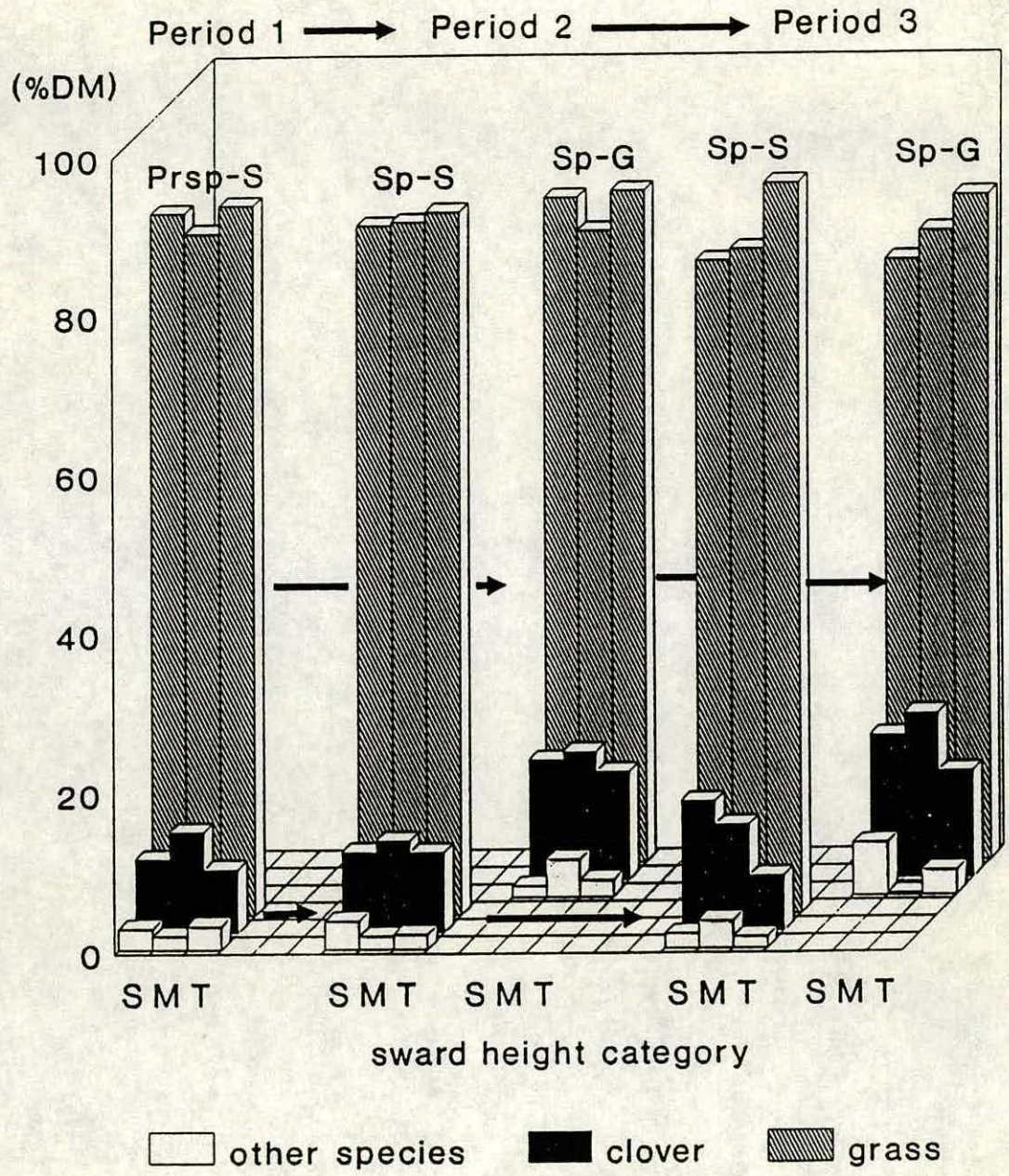


Figure 3.16. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species in the whole sward, divided into three sward height categories: short (S), medium (M) and tall (T) grazed either by sheep (Sp-S) or goats (Sp-G) in Phase 2 (Periods 2 and 3) after have been grazed by goats (Prsp-G) in Phase 1. For comparison, the data from Period 1 is also given.

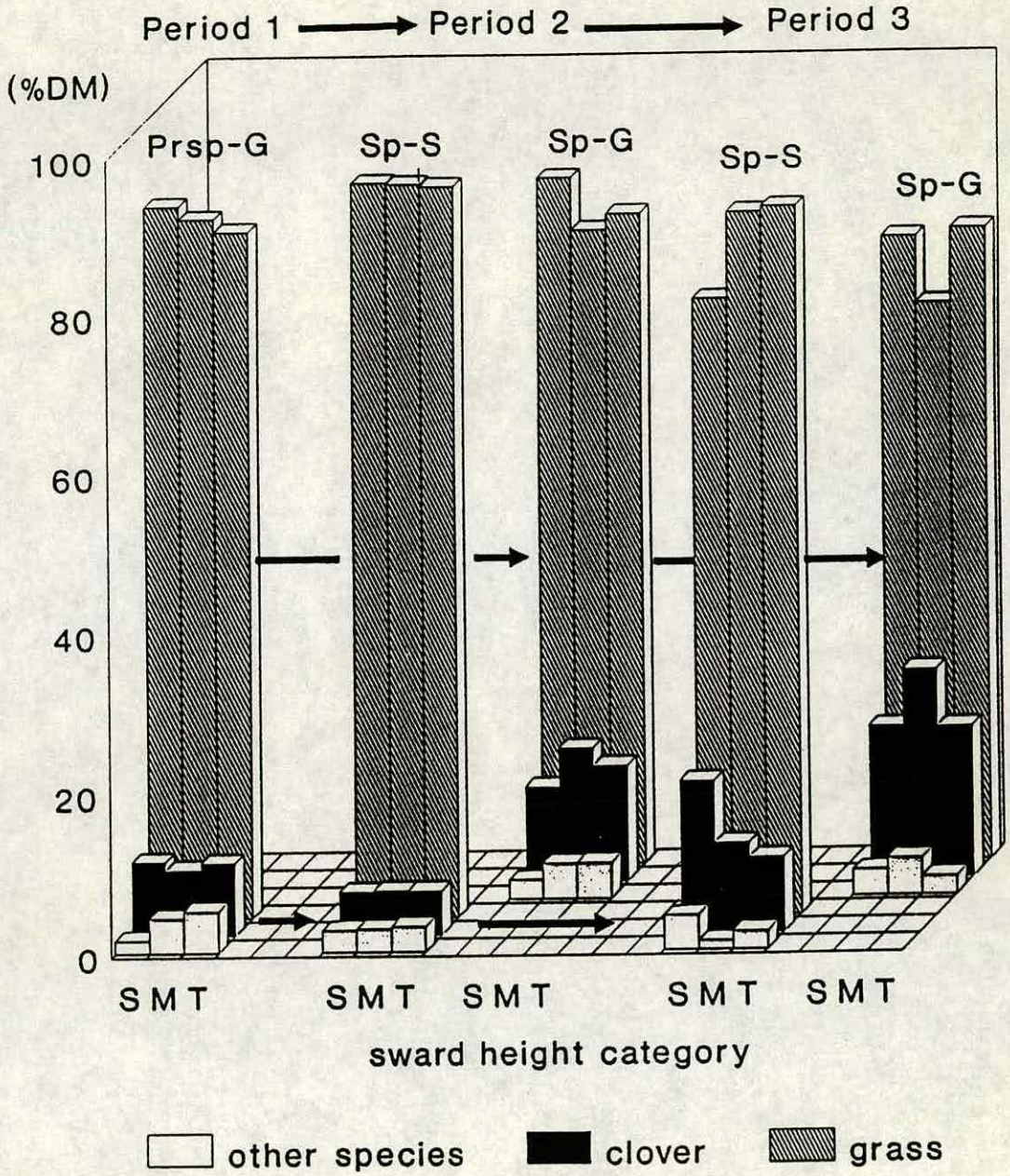
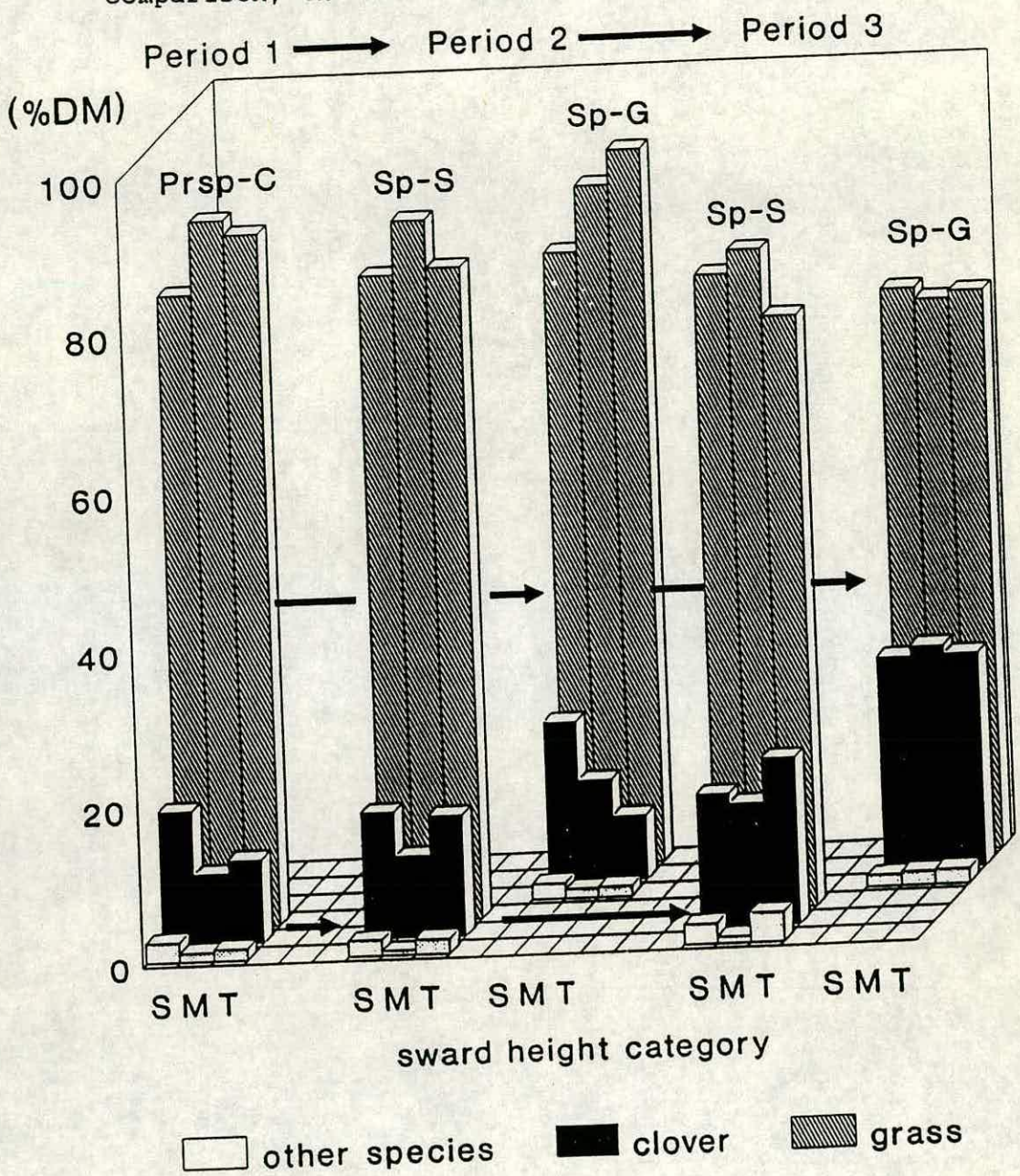


Figure 3.17. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species in the whole sward, divided into three sward height categories: short (S), medium (M) and tall (T), grazed either by sheep (Sp-S) or goats (Sp-G) in Phase 2 (Periods 2 and 3) after have been grazed by cattle (Prsp-C) in Phase 1. For comparison, the data from Period 1 is also given.



Changes in the percentage of clover between Periods 1 and 3 within sward height category between pre-species were +8.0%, +9.6% and +5.0% on the short category, +4.3%, +10.2% and +13.0% on the medium category and +2.3%, +5.0% and +13.7% on the tall category for Prsp-S, Prsp-G and Prsp-C treatments respectively (overall sed. 4.92; ns). Since clover lamina-petiole accounted for the majority of clover, in Period 2 the interaction of pre-species x sward height category was significant for the percentage of clover lamina-petiole ($p<0.05$): the Prsp-C treatment had higher percentages of clover lamina-petiole than the Prsp-S and Prsp-G treatments on the short and on the tall categories while the Prsp-S treatment had the highest percentage on the medium category. The Prsp-G treatment had higher percentages of clover flower ($p<0.001$) on the short height category. On the Prsp-C plots there was a higher percentage of dead clover on the short ($p<0.05$), medium (ns) and tall categories (ns). Finally, in Period 2, Prsp-G plots had a higher percentage of grass leaf on the short ($p<0.05$), medium (ns) and tall categories ($p<0.05$) but tended to have lower percentage of dead grass on the three height categories ($p<0.1$). In Period 3 there were no significant effects of pre-species or species on any grass components.

Within sward height category, the Sp-G treatment resulted in larger clover percentage than the Sp-S treatment on the short (+9.6% versus +5.5%), on the medium (+15.0 versus +3.3%) and on the tall categories (+10.7% versus +3.3%; overall sed. 5.16; ns). Thus grazing by goats resulted in greater percentages of clover compared to grazing by sheep during both sampling periods in the short category: 15.8% versus 10.5% in Period 2 ($p<0.05$) and 21.4% versus 17.3% in Period 3 (ns), in the medium category: 15.1% versus 9.1% in Period 2 ($p<0.01$) and 25.0% versus 13.3% in Period 3 ($p<0.05$) and in the tall category:

12.0% versus 10.3% in Period 2 (ns) and 19.8% versus 12.5% in Period 3 (ns) with overall sed. 1.87 and 5.05 for Periods 2 and 3 respectively. Similarly, percentages of clover lamina-petiole were higher on the Sp-G treatment than on the Sp-S treatment across the three height categories.

Between Periods 1 and 2, on the Prsp-G treatment, Sp-S treatment decreased the percentage of clover in all height categories while Sp-G treatment increased it ($p<0.05$; see Figure 3.16). Sp-G treatment showed larger increases than Sp-S treatment in all pre-species treatments for medium ($p<0.1$) and tall categories ($p<0.05$) but non significantly for short categories (see Figures 3.16, 3.17 and 3.18). The three way interaction of pre-species x species x sward height category was only significant for the percentages of dead grass ($p<0.05$) and other species ($p<0.05$) in Period 3.

The vertical distributions (kg DM/ha) of each of the botanical components in the sward in Periods 2 and 3 plotted for the interaction of pre-species x species x sward category x horizon, are given graphically in Appendix 1, in Figures A1.10 to A1.18 (Period 2) and from Figures A1.19 to A1.27 (Period 3). Figures 3.18 (Period 2) and 3.20 (Period 3) display the vertical distribution of the amounts of grass and Figures 3.19 (Period 2) and 3.21 (Period 3) the amounts of clover classified by pre-species, species, sward height category and horizon.

In both sampling periods (Periods 2 and 3) all four horizons had highly significantly different amounts of all botanical components ($p<0.001$), except for clover flower ($p=0.053$ and ns in Periods 2 and 3 respectively; see Tables 3.14, 3.15, 3.16 and 3.17).

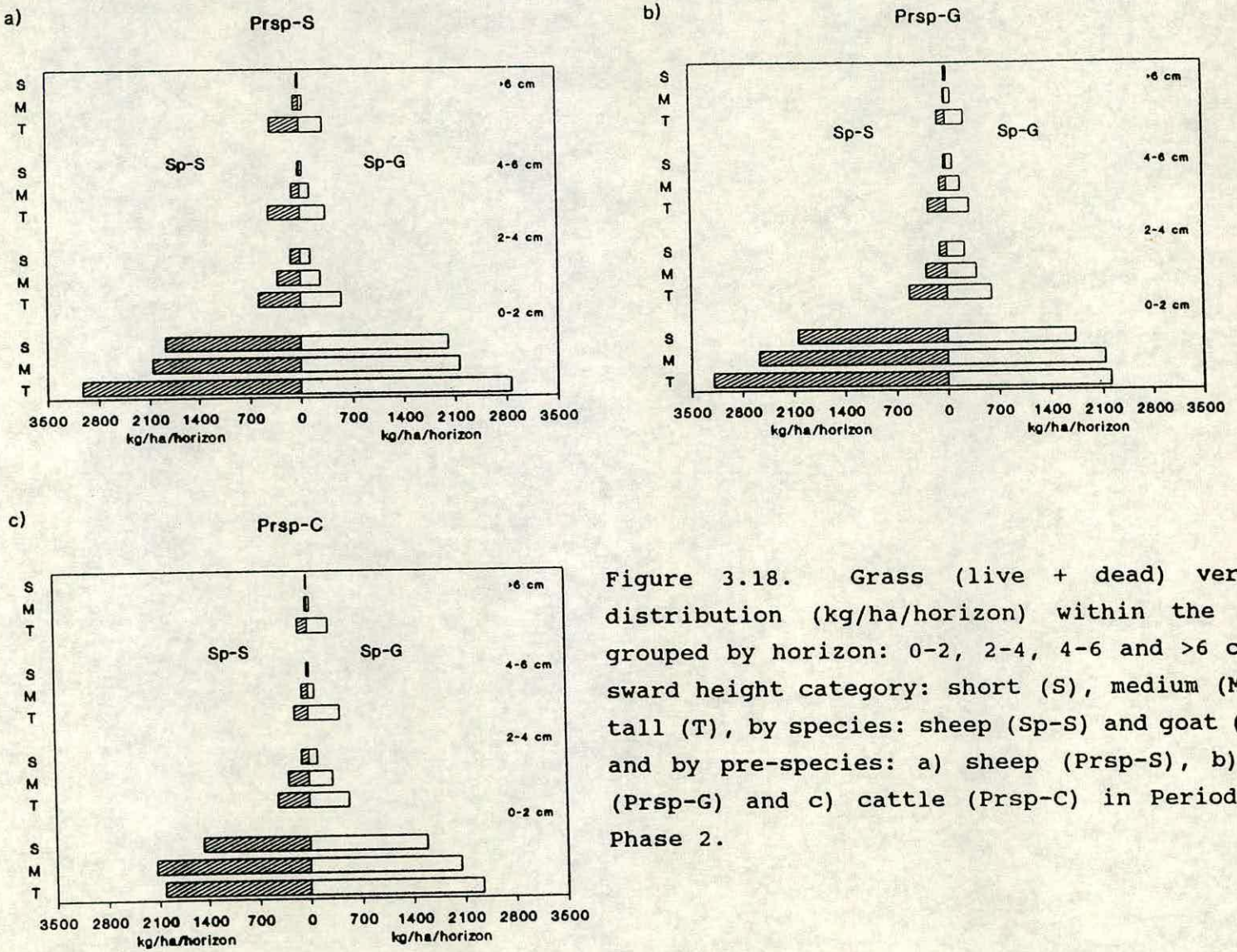


Figure 3.18. Grass (live + dead) vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

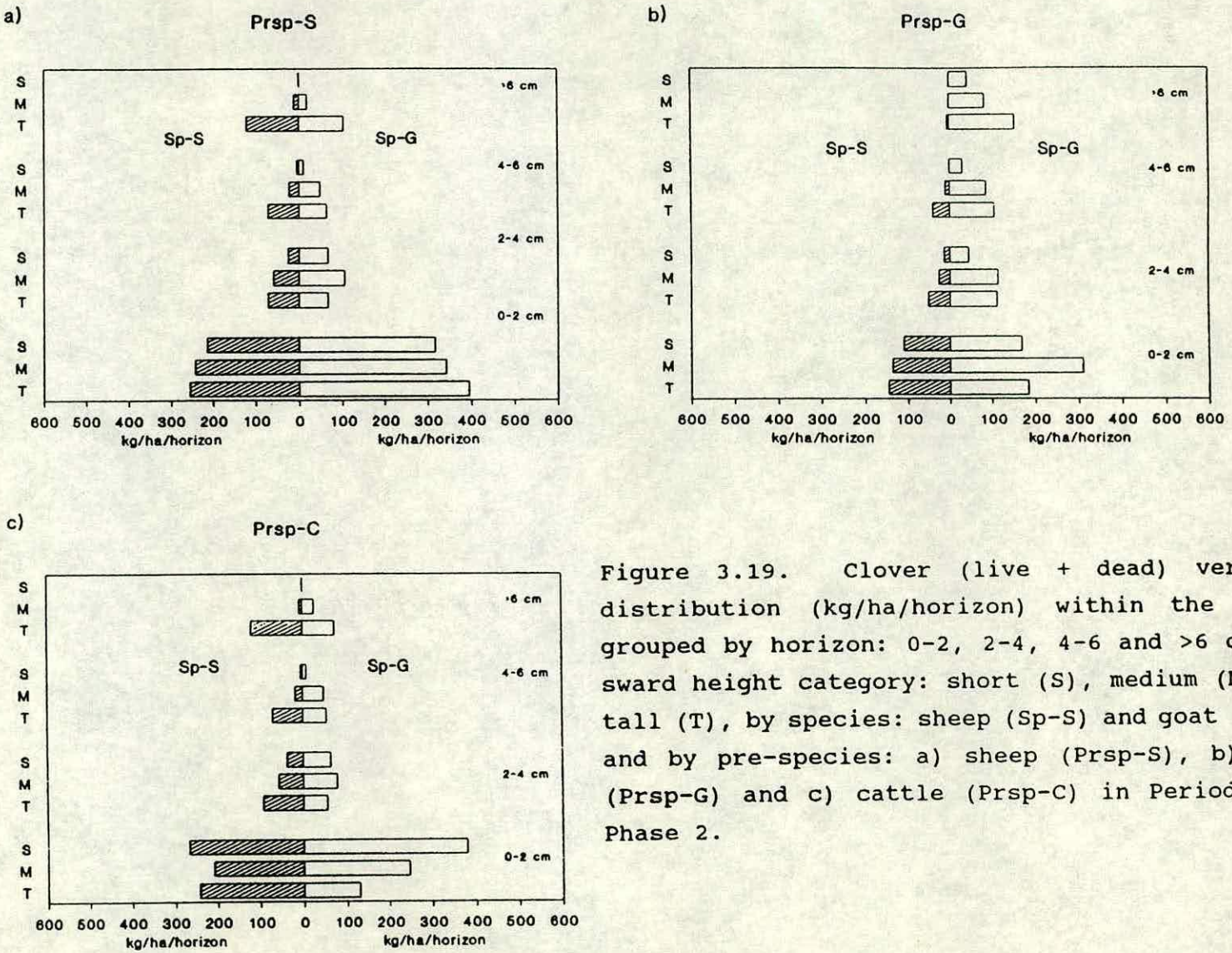


Figure 3.19. Clover (live + dead) vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

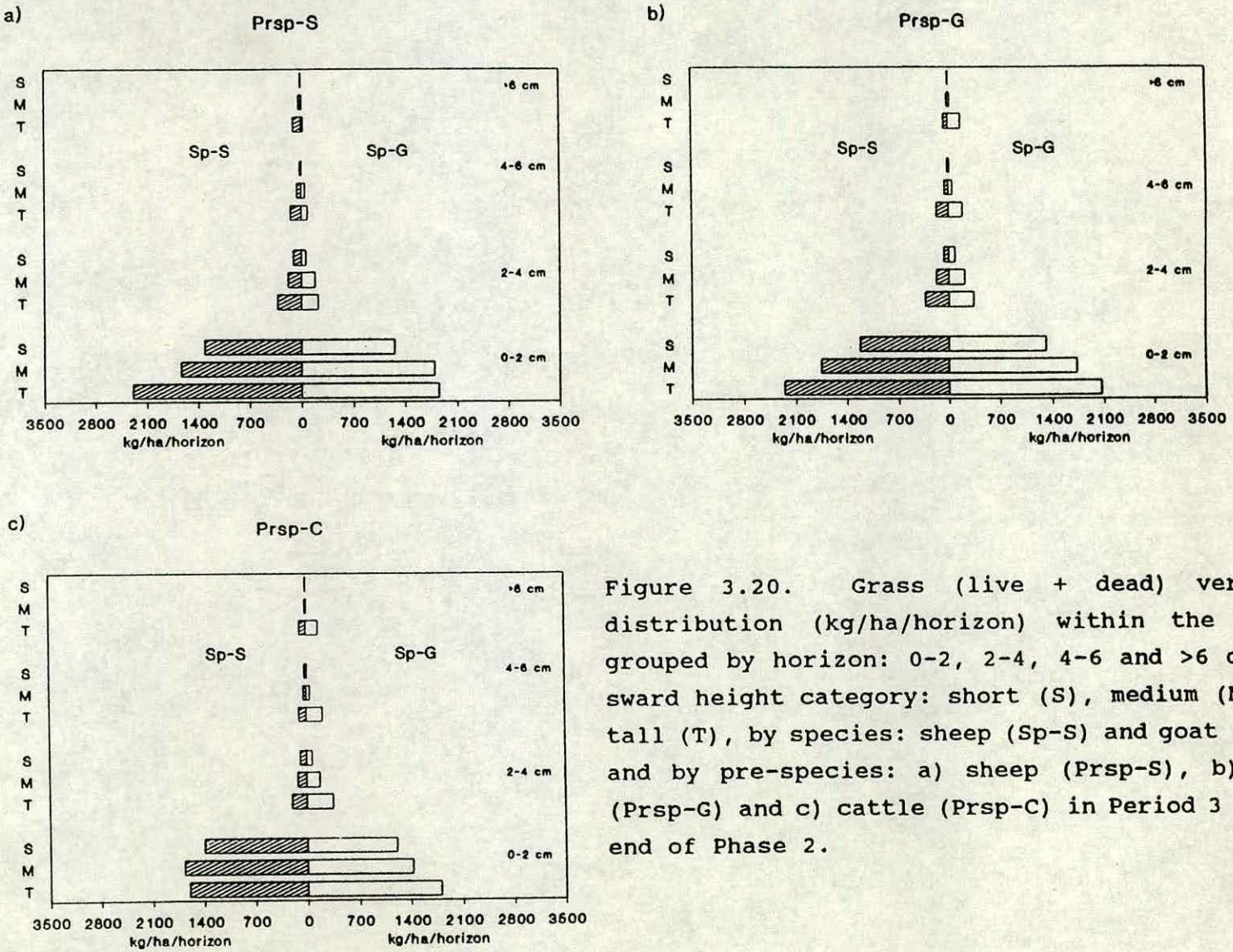


Figure 3.20. Grass (live + dead) vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

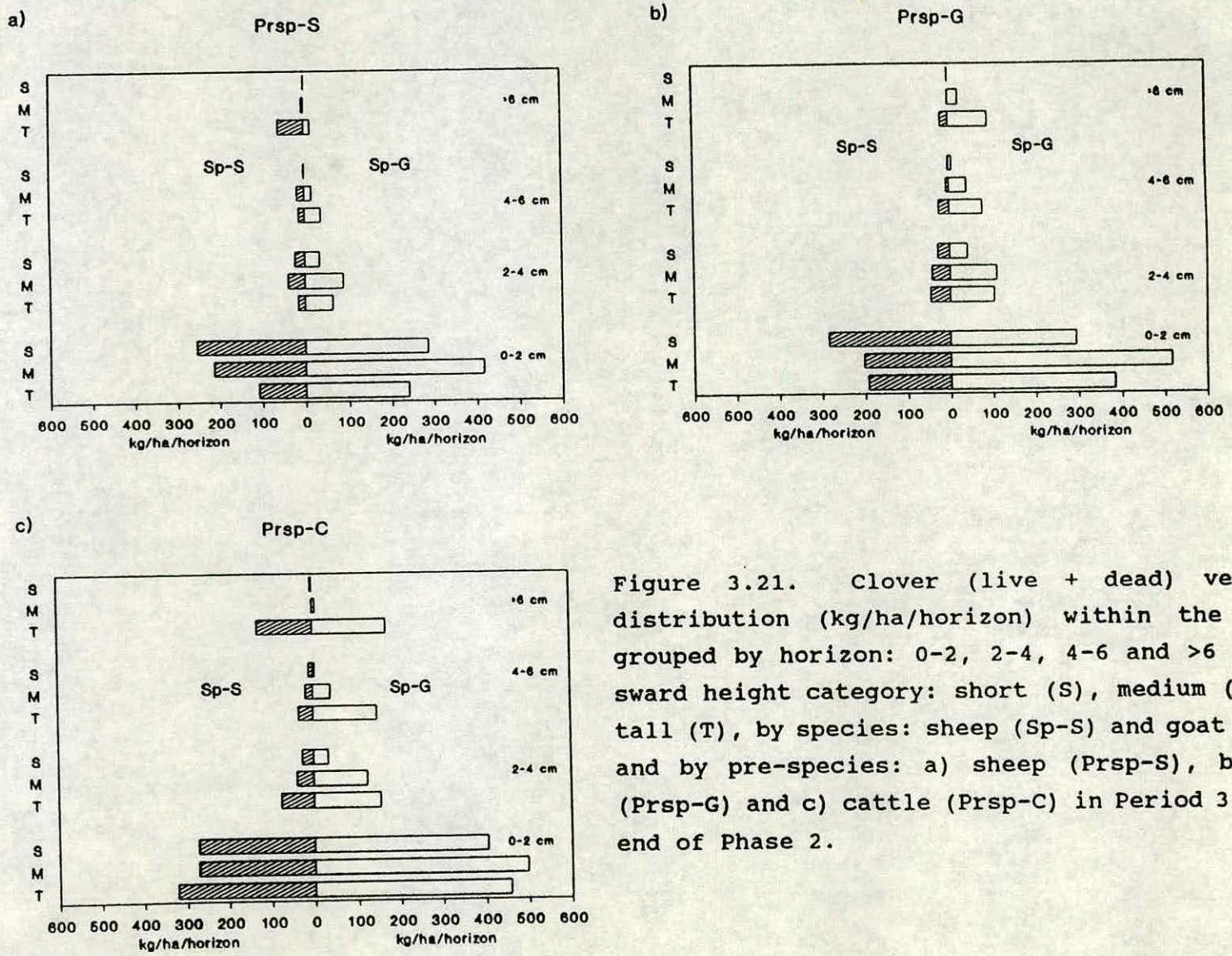


Figure 3.21. Clover (live + dead) vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

Table 3.14. Botanical components (kg/ha/horizon) of the whole sward classified by pre-species treatment, by species treatment, by sward height category and by horizon in Period 2 in Phase 2. Levels of significance are given in Table 3.15.

Pre-species		Sheep						Goat						Cattle					
Species		Sheep			Goat			Sheep			Goat			Sheep			Goat		
Height category		Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall
Component	Horizon (cm)																		
Grass leaf	0-2	835	1033	1008	959	989	1130	945	1210	1198	793	921	948	723	904	778	721	793	655
	2-4	101	243	356	105	199	374	86	239	374	188	298	426	84	215	302	88	226	283
	4-6	20	88	320	23	101	247	30	80	201	73	151	254	19	74	147	14	64	272
	>6	3	26	207	2	38	238	2	22	84	25	59	217	6	18	107	2	26	188
Grass pseudostem	0-2	266	371	718	279	387	586	325	401	669	274	433	415	195	403	390	242	430	528
	2-4	11	10	86	2	23	51	6	15	69	12	36	63	4	16	45	9	34	94
	4-6	0	4	40	0	9	17	1	3	20	2	12	13	1	4	17	2	10	56
	>6	1	0	9	0	4	11	1	1	5	0	3	13	1	0	6	0	1	34
Grass flowerstem	0-2	63	82	296	98	122	128	147	142	303	88	108	146	104	148	156	105	130	246
	2-4	3	13	47	11	17	34	3	5	31	12	23	45	5	16	27	7	10	54
	4-6	5	3	28	3	11	45	0	7	12	7	10	18	0	2	14	0	1	30
	>6	17	47	140	0	4	48	4	0	23	2	10	15	0	7	12	0	4	24
Dead grass	0-2	714	569	1005	669	666	1022	620	623	1029	578	684	705	439	674	694	525	702	925
	2-4	22	47	88	15	25	91	8	29	52	27	42	66	9	35	55	10	45	103
	4-6	6	17	49	3	7	34	2	5	21	5	17	23	2	6	14	1	8	62
	>6	1	4	46	0	3	19	0	0	5	2	3	5	1	1	7	0	3	35
Clover lamina-petiole	0-2	162	176	166	272	273	264	79	101	114	140	232	160	228	163	196	311	205	102
	2-4	23	52	56	51	101	61	14	26	51	41	104	105	36	51	86	62	75	51
	4-6	3	21	68	10	47	61	0	11	40	31	85	95	5	14	65	8	47	53
	>6	0	12	106	0	15	102	0	0	5	25	78	152	0	0	115	0	26	66
Clover stolon	0-2	41	63	78	36	55	222	19	15	18	11	65	10	26	28	26	45	26	18
	2-4	3	5	7	14	2	0	0	0	1	1	0	1	0	0	0	0	1	0
	4-6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	>6	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clover flower	0-2	4	1	3	1	0	6	10	7	2	7	0	0	5	4	12	4	2	0
	2-4	0	0	0	1	0	0	0	0	0	1	0	0	0	3	1	0	0	0
	4-6	0	2	0	0	0	3	0	0	0	0	0	10	0	3	1	0	0	0
	>6	0	0	3	0	4	0	0	0	0	18	5	0	0	6	3	0	0	7
Dead Clover	0-2	7	3	8	8	13	4	3	13	13	12	13	13	7	13	9	20	13	10
	2-4	0	1	9	0	2	5	0	1	1	1	10	5	0	2	6	1	2	4
	4-6	0	0	3	0	1	0	0	1	1	0	1	1	0	1	3	0	0	1
	>6	0	0	10	0	0	1	0	0	0	0	1	2	0	0	0	0	0	0
Other species	0-2	78	33	37	36	95	41	63	66	88	51	107	72	38	18	47	44	25	34
	2-4	4	15	35	1	16	26	2	16	36	1	20	33	0	1	12	0	5	6
	4-6	0	2	1	0	11	13	0	8	10	1	3	31	0	0	3	0	2	9
	>6	0	0	7	0	18	30	0	4	18	3	0	53	0	0	0	0	0	2

Table 3.15. Summary of the results of the analysis of variance of the effects of pre-species treatment (sheep, goats and cattle), species tretament (sheep and goats), sward height category (short, medium and tall), horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) and their interactions on the nine major botanical components in Period 2 in Phase 2.

	Grass leaf	Grass pseudostem	Grass flowerstem	Dead grass	Clover lamina-petiole	Clover stolon	Clover flower	Dead clover	Other species
Pre-species (Prsp)	p=0.064	ns	ns	ns	ns	ns	ns	ns	ns
Species (Sp)	ns	ns	ns	ns	•••	ns	ns	ns	ns
Sward height category (Sc)	•••	•••	••	•••	•	ns	ns	ns	ns
Horizon (H)	•••	•••	•••	•••	•••	•••	p=0.053	•••	•••
(Prsp x Sp)	ns	ns	ns	ns	•••	ns	ns	ns	ns
(Prsp x Sc)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Sp x Sc)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Prsp x Sp x Sc)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Prsp x H)	ns	ns	ns	ns	••	••	ns	p=0.069	ns
(Sp x H)	ns	ns	ns	ns	ns	ns	ns	p=0.053	ns
(Sc x H)	ns	•••	••	••	•••	ns	ns	ns	ns
(Prsp x Sc x H)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Sp x Sc x H)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Prsp x Sp x H)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Prsp x Sp x Sc x H)	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 3.16. Botanical components (kg/ha/horizon) of the sward classified by pre-species, by species, by sward height category and by horizon in Period 3 at the end of Phase 2.

Pre-species		Sheep						Goat						Cattle					
Species		Sheep			Goat			Sheep			Goat			Sheep			Goat		
Height Category		Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall	Short	Medium	Tall
Component	Horizon (cm)																		
Grass leaf	0-2	723	865	1125	676	877	905	661	857	909	653	892	941	771	843	733	612	707	880
	2-4	92	148	241	54	154	184	56	138	240	70	183	254	74	96	137	55	145	253
	4-6	18	50	115	9	41	67	12	40	132	18	52	142	21	39	80	10	44	169
	>6	4	13	63	1	10	20	1	9	49	4	29	148	6	11	79	1	13	128
Grass pseudostem	0-2	174	253	401	222	317	361	164	298	415	225	356	443	179	272	268	282	302	423
	2-4	4	13	30	3	10	17	5	6	37	7	16	51	8	15	42	5	6	51
	4-6	1	4	13	0	1	1	1	3	10	0	1	26	1	3	15	0	0	19
	>6	0	1	1	0	0	0	0	0	4	0	0	9	1	1	4	0	0	6
Grass flowerstem	0-2	55	83	124	35	76	52	94	1	135	52	36	52	81	21	71	26	0	7
	2-4	5	10	18	3	2	4	2	11	15	4	2	12	4	4	5	4	0	1
	4-6	2	5	16	0	0	2	0	4	14	1	0	13	2	0	2	0	0	1
	>6	3	22	41	0	0	8	0	7	8	0	0	8	0	0	0	0	0	13
Dead grass	0-2	366	436	645	326	524	537	310	598	802	389	450	635	364	531	530	294	415	497
	2-4	9	8	31	2	12	16	4	19	40	7	20	27	3	9	20	10	22	44
	4-6	1	2	7	0	1	10	1	6	15	1	1	11	1	1	6	1	3	23
	>6	0	2	3	0	0	3	0	2	2	0	1	5	1	1	2	0	1	13
Clover lamina-petiole	0-2	216	164	88	229	363	193	230	177	162	270	442	332	217	206	249	349	421	358
	2-4	23	35	15	33	87	63	29	42	46	40	107	101	25	32	60	34	110	146
	4-6	1	17	14	0	16	37	3	7	18	7	41	76	9	17	26	4	40	139
	>6	0	5	49	0	0	14	0	0	19	0	24	92	3	0	97	0	7	144
Clover stolon	0-2	27	39	16	36	29	36	48	22	26	12	33	27	43	59	45	49	44	49
	2-4	0	3	1	0	0	0	0	1	0	0	0	2	1	1	8	0	0	0
	4-6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
	>6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Clover flower	0-2	8	0	0	2	0	0	0	0	0	2	24	1	0	0	9	1	3	4
	2-4	0	0	0	0	0	1	0	0	0	1	2	0	0	6	0	0	10	0
	4-6	0	0	0	0	0	0	0	0	5	0	0	0	0	0	4	0	0	0
	>6	0	0	11	0	0	0	0	0	0	8	0	0	0	0	32	0	0	26
Dead Clover	0-2	4	11	5	19	24	11	6	3	6	12	19	25	11	6	18	6	31	47
	2-4	0	1	0	0	0	0	0	0	0	0	1	1	0	0	8	0	3	8
	4-6	0	1	0	0	0	0	0	0	2	0	0	3	0	0	3	1	0	6
	>6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Other species	0-2	34	68	36	109	7	62	71	24	54	50	120	33	47	18	50	18	34	40
	2-4	0	4	6	7	0	16	2	2	5	4	15	14	0	1	26	8	5	17
	4-6	0	0	3	0	0	1	0	8	13	1	3	26	0	0	17	0	3	4
	>6	0	0	2	0	0	0	0	0	0	0	0	6	0	0	7	0	0	9

Table 3.17. Summary of the results of the analysis of variance of the effects of pre-species treatment (sheep, goats and cattle), species treatment (sheep and goats), sward height category (short, medium and tall), horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) and their interactions on the nine major botanical components in Period 3 at the end of Phase 2.

	Grass leaf	Grass pseudostem	Grass flowerstem	Dead grass	Clover lamina-petiole	Clover stolon	Clover flower	Dead clover	Other species
Pre-species (Prsp)	ns	ns	ns	ns	ns	ns	ns	•	ns
Species (Sp)	ns	ns	ns	ns	•	ns	ns	•	ns
Sward height category (Sc)	•••	•••	••	•••	•	ns	ns	ns	ns
Horizon (H)	•••	•••	•••	•••	•••	•••	ns	•••	•••
(Prsp x Sp)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Prsp x Sc)	ns	ns	p=0.053	ns	p=0.062	ns	ns	ns	ns
(Sp x Sc)	ns	ns	p=0.057	ns	•	ns	ns	ns	ns
(Prsp x Sp x Sc)	•	ns	ns	ns	ns	ns	ns	ns	•
(Prsp x H)	ns	ns	ns	ns	•	••	ns	ns	•
(Sp x H)	ns	ns	ns	ns	•••	ns	ns	•••	ns
(Sc x H)	p=0.074	••	ns	•••	•••	ns	•	ns	ns
(Prsp x Sc x H)	ns	ns	ns	ns	ns	ns	p=0.070	ns	ns
(Sp x Sc x H)	ns	ns	ns	ns	••	ns	ns	ns	ns
(Prsp x Sp x H)	ns	ns	ns	ns	ns	ns	ns	ns	ns
(Prsp x Sp x Sc x H)	ns	ns	ns	ns	ns	ns	ns	ns	•••

Overall amounts of clover in Period 2 were: 239, 63, 38 and 42 kg/ha/horizon (sed. 10.5; $p<0.001$) and in Period 3: 312, 60, 28 and 29 kg/ha/horizon (sed. 49.0; $p<0.001$) for 0-2, 2-4, 4-6 and >6 cm horizons respectively while amounts of grass were 2194, 328, 159 and 103 kg/ha/horizon (sed. 36.4; $p<0.001$) in Period 2 and 1646, 184, 73 and 42 kg/ha/horizon (sed. 49.0; $p<0.001$) in Period 3 for 0-2, 2-4, 4-6 and >6 cm horizons respectively. Changes between Period 1 and Period 3, i.e. during Phase 2, in botanical components between horizons were overall significant for clover (+63.6, +4.9, -12.1 and +0.2 kg/ha; sed. 12.33; $p<0.001$), clover lamina-petiole (+84.5, +8.6, -4.7 and -2.1 kg/ha; sed. 8.25; $p<0.001$), dead clover (+6.38, -0.69, -2.20 and -0.53 kg/ha; sed. 1.73; $p<0.01$), grass (-883.0, -203.0, -110.0, -113.0 kg/ha; sed. 38.2; $p<0.001$), grass pseudostem (-206.6, -27.2, -9.6 and -10.1 kg/ha; sed. 13.81; $p<0.001$), grass flowerstems (-60.3, 11.7, -10.5 and -14.3 kg/ha; sed. 6.39; $p<0.001$) and dead grass (-628, -46, -11 and -11; sed. 21.1; $p<0.001$). Clover flower increased ($p<0.01$) its presence in the highest horizon (>6 cm) significantly while the clover stolon mass decreased in the 0-2 cm horizon ($p<0.001$).

From Period 1 to Period 2 amounts of clover lamina-petiole decreased in the 0-2 cm horizon of the Prsp-G treatment and in the >6 cm horizon of the Prsp-C treatment ($p<0.05$) while dead grass diminished more markedly on the Prsp-G and Prsp-C than on the Prsp-S treatments ($p<0.05$). In Periods 2 and 3, the interaction of pre-species x horizon was significant for the distribution of the amounts of clover lamina-petiole ($p<0.01$ and $p<0.05$ respectively) with greater increases during Phase 2 (from Period 1 to Period 3) on the Prsp-C and Prsp-G treatments than on the Prsp-S treatment in the 0-2 cm (+116.9 and +94.4 versus +42.4 kg/ha) and 2-4 cm horizons (+16.5 and +7.1 versus +2.1 kg/ha) while there was a decrease on the Prsp-C

treatment in the >6 cm horizon (+6.0 and +6.7 versus -19.0 kg/ha for Prsp-S, Prsp-G and Prsp-C treatments respectively) (overall sed. 17.35; $p<0.05$). Also, amounts of clover stolon differed within horizon between pre-species treatments with the greatest decrease in the 0-2 cm horizon on the Prsp-S treatment ($p<0.01$ and $p<0.01$ respectively). Clover flower increased more in the >6 cm horizon on the Prsp-C treatment than on the Prsp-S and Prsp-G treatments (+9.6 versus +1.8 and +0.1 kg/ha respectively; sed. 3.30; $p<0.01$). The Sp-G treatment resulted in greater amounts of clover lamina-petiole throughout all the horizons but the amounts were only significantly greater in the 0-2 cm horizon (pre-species x horizon; $p<0.001$ in Period 3). The same was true for dead clover (pre-species x horizon; $p<0.001$ in Period 3).

Taller height categories had more clover lamina-petiole in the upper horizons (4-6 cm and >6 cm horizons) in both sampling periods, as would be expected, and more dead grass near to ground level (0-2 cm horizon) than the medium and short categories. Also the taller height category had more clover flower in the upper horizons (4-6 cm and >6 cm horizons) than the medium and short categories.

There were no overall significant interactions between pre-species, species, horizon and sward height category in any grass and clover component.

3.4.4.2.2. *Sward surface.*

While the composition in terms of percentages of grass and clover is given in Table 3.18, Tables 3.19 and 3.20 describe the sward surface composition in terms of the percentages of the different botanical components in Periods 2 and 3 respectively.

From Period 1 to Period 3, greater increases in percentage of clover on the sward surface occurred on Prsp-C treatment (+15.6%) than on Prsp-S (+11.9%) and Prsp-G treatments (+8.9%; sed. 8.84; ns) although the differences between pre-species treatments were not significant. On the sward surface of the Prsp-S, Prsp-G and Prsp-C treatments the total clover and total grass percentages were 21.2%, 20.1% and 23.4% clover (sed. 5.37; ns) and 75.6%, 75.6% and 75.8% grass (sed. 6.55; ns) respectively in Period 2 and 23.0%, 24.7% and 33.8% clover (sed. 3.59; ns) and 75.0%, 72.4% and 63.4% grass (sed. 5.02; ns) respectively in Period 3. There was a tendency for the Prsp-C treatment to have higher percentages of clover lamina-petiole (ns), clover stolon (ns), clover flower (ns) and grass pseudostem (ns) but lower percentages of grass flowerstem ($p<0.05$ in Period 3) and of other species (ns) on the surface.

The sward surface on the goat-grazed plots (Sp-G) had a greater percentage of clover than on the sheep-grazed plots (Sp-S): 26.5% versus 16.6% in Period 2 (sed. 2.90; $p<0.05$) and 31.9% versus 22.4% in Period 3 (sed. 10.16; ns). Also Sp-G plots had higher percentages of clover lamina-petiole than Sp-S plots in Period 2 (25.3% versus 15.4%; sed. 2.30; $p<0.01$) and in Period 3 (30.2% versus 19.2%; sed. 9.30; ns).

Table 3.18. Percentages of total grass and total clover dry matter components (live + dead) on the sward surface classified by pre-species treatment and by species treatment in Periods 2 and 3 in Phase 2.

	Pre-species (Prsp)	sheep		goat		cattle			Level of significance		
	Species (Sp)	sheep	goat	sheep	goat	sheep	goat	sed	Prsp	Sp	Prsp x Sp
	Period										
Grass	2	80.4	70.8	87.2	64.0	75.9	75.7	6.55[a]/ 6.15[b]	ns	p=0.053	ns
	3	78.8	71.2	80.0	64.8	67.8	59.1	12.55[a]/16.26[b]	ns	ns	ns
Clover	2	17.2	25.1	9.3	30.8	23.2	23.5	6.43[a]/ 5.01[b]	ns	*	ns
	3	20.2	25.7	17.8	31.6	29.1	38.5	12.95[a]/17.60[b]	ns	ns	ns

([a]- sed. of means with different pre-species level [b]- sed. of means with same pre-species level)

Table 3.19. Botanical components (%DM) on the sward surface classified by pre-species treatment, by species treatment and by sward height category in Period 2 in Phase 2.

	Pre-species (Prsp)	sheep		goat		cattle			Level of significance
	Species (Sp)	sheep	goat	sheep	goat	sheep	goat	sed	
Component	Height Category (Sc)								
Grass leaf	Short	51.2	47.0	68.1	65.1	51.4	47.2		
	Medium	61.1	50.6	75.2	52.4	60.1	55.6	11.10*	
	Tall	53.1	51.9	68.0	47.4	47.5	55.9		
Grass pseudostem	Short	7.0	6.4	7.0	3.5	6.8	6.6		
	Medium	2.3	4.3	3.0	2.8	7.2	7.1	2.48*	
	Tall	3.1	2.6	5.7	2.4	7.0	7.9		
Grass flowerstem	Short	4.1	4.7	2.5	4.8	4.5	3.8		
	Medium	8.3	3.7	2.3	3.7	3.5	1.4	4.23*	Sc (p=0.069)
	Tall	15.8	11.4	5.7	3.5	5.5	7.0		
Dead grass	Short	21.7	17.9	11.9	8.3	15.5	9.7		
	Medium	11.5	4.3	6.6	5.6	14.8	7.1	4.43*	Sp (p=0.070), Sc **
	Tall	7.0	4.8	6.3	1.5	8.1	12.0		
Clover lamina-petiole	Short	11.7	19.0	7.9	16.7	19.5	31.1		
	Medium	14.8	26.6	8.3	34.1	13.0	27.2	8.13*	Sp **, Prsp x Sp *, Prsp x Sp x Sc (p=0.064)
	Tall	17.7	25.1	9.9	34.7	29.6	15.9		
Clover stolon	Short	1.0	4.0	0.3	0.5	0.8	0.6		
	Medium	0.8	0.1	0.0	0.0	0.3	0.4	1.01*	Sc *
	Tall	0.1	0.0	0.0	0.0	0.2	0.0		
Clover flower	Short	0.1	0.0	0.6	0.5	0.1	0.1		
	Medium	0.1	0.1	0.1	0.1	0.4	0.0	0.25*	
	Tall	0.1	0.1	0.0	0.1	0.3	0.2		
Dead clover	Short	0.3	0.2	0.1	0.3	0.3	0.8		
	Medium	0.0	0.2	0.5	0.1	0.6	0.2	0.43*	
	Tall	1.1	0.1	0.1	0.3	0.3	0.1		
Other species	Short	2.9	0.9	1.6	0.4	1.2	0.1		
	Medium	1.1	10.2	4.0	1.2	0.1	0.9	3.88*	
	Tall	2.0	4.1	4.2	10.1	1.5	1.0		

(*- sed. of means of the interaction Prsp x Sp x Sc).

Table 3.20. Botanical components (%DM) on the sward surface classified by pre-species treatment, by species treatment and by sward height category in Period 3 at the end of Phase 2.

	Pre-species (Prsp)	sheep		goat		cattle			Level of significance
	Species (Sp)	sheep	goat	sheep	goat	sheep	goat	sed	
Component	Height Category (Sc)								
Grass leaf	Short	56.3	48.6	55.1	45.9	55.3	41.7		
	Medium	61.2	64.6	65.2	55.3	60.9	48.4	12.01*	
	Tall	54.9	61.0	62.0	49.4	48.2	41.9		
Grass pseudostem	Short	7.3	7.8	7.2	9.8	8.7	11.2		
	Medium	5.3	2.3	3.7	3.5	7.4	1.2	3.34*	Sc **
	Tall	3.6	2.1	5.6	6.8	5.7	2.9		
Grass flowerstem	Short	3.4	2.7	3.2	2.8	3.9	2.5		
	Medium	6.9	0.7	6.3	0.6	1.5	0.0	5.39*	Prsp *
	Tall	16.0	2.1	7.3	3.6	0.6	2.5		
Dead grass	Short	15.3	9.5	8.8	12.4	13.2	14.1		
	Medium	3.0	3.1	9.5	4.0	4.0	5.6	4.49*	Sc ***
	Tall	3.5	6.2	6.2	3.4	2.5	5.1		
Clover lamina-petiole	Short	15.3	25.0	23.3	25.2	16.8	25.3		
	Medium	21.9	29.2	14.6	32.6	23.3	40.7	14.19*	
	Tall	17.5	26.6	13.1	32.1	25.8	40.1		
Clover stolon	Short	0.9	1.0	0.5	0.3	2.2	2.0		Sc ***,
	Medium	0.4	0.0	0.2	0.0	0.3	0.0	0.57*	Prsp x Sc **
	Tall	0.0	0.0	0.0	0.0	0.3	0.3		
Clover flower	Short	0.4	0.0	0.0	0.7	0.0	0.0		Sc **,
	Medium	0.0	0.0	0.0	0.4	2.3	1.6	1.93*	Prsp x Sc (p=0.064)
	Tall	3.5	0.0	1.7	0.0	8.0	4.4		
Dead clover	Short	0.1	0.5	0.1	0.1	0.5	0.3		
	Medium	0.6	0.0	0.0	0.2	0.0	0.5	0.39*	
	Tall	0.0	0.0	0.6	0.4	0.6	0.8		
Other species	Short	1.1	4.9	1.8	2.9	1.5	3.0		
	Medium	0.7	0.0	0.4	3.4	0.4	2.0	2.74*	
	Tall	1.0	2.0	3.6	4.2	8.4	2.0		

(*- sed. of means of the interaction Prsp x Sp x Sc).

Also in Period 2 Sp-G plots had lower percentage of dead grass (7.7% versus 11.0%; sed. 1.17; $p<0.1$) than Sp-S plots.

There was a significant ($p<0.05$) interaction between pre-species and species in the percentage of clover lamina-petiole on the sward surface in Period 2 such that there was more clover lamina-petiole on the Sp-G treatment compared to the Sp-S treatment when previously grazed by sheep and goats, but not on those previously grazed by cattle. Although this trend was evident for total clover it did not achieve statistical significant.

Percentages of clover and grass on the surface of short, medium and tall categories did not differ greatly: 19.4%, 21.3% and 22.7% for clover (sed. 2.56) and 79.5%, 75.8% and 73.5% for grass (sed. 2.49) in Period 2 and 23.4%, 28.1% and 29.3% for clover (sed. 4.67) and 74.1%, 70.7% and 67.2% (sed. 4.36) for grass in Period 3.

During Phase 2 for both sampling periods, the interaction of pre-species x species x sward height category showed differences in the percentage of clover on the sward surface ($p<0.05$ for both periods). The Sp-G treatment had higher percentage values of clover than the Sp-S treatment in Period 2 on the Prsp-S plots: 23.2% versus 13.0% (short), 27.0% versus 15.7% (medium) and 25.2% versus 19.0% (tall), on the Prsp-G plots: 17.9% versus 8.9% (short), 34.3% versus 8.9% (medium), and 35.2% versus 10.1% (tall) and also on the short and on medium height categories on the Prsp-C plots: 32.5% versus 20.7% and 27.8% versus 14.3% respectively but not on the tall category on the Prsp-C plots: 16.1% versus 30.4% (overall sed. 8.26; $p=0.055$). Similar differences also occurred in Period 3 for the Prsp-S plots: 26.5% versus 16.7% (short), 29.2% versus 22.9% (medium) and 26.7% versus 21.0% (tall),

for the Prsp-G plots: 26.3% versus 24.0% (short), 33.2% versus 14.8% (medium) and 32.6% versus 15.4% (tall) and for the Prsp-C plots: 27.5% versus 19.4% (short), 42.8% versus 25.8% (medium) and 45.6% versus 34.7% (tall)(overall sed. 14.70; ns).

Figures 3.22, 3.23 and 3.24 display graphically the changes during Phase 2 (with Period 1 as reference) in percentages of clover, grass and other species on the sward surface of Prsp-S, Prsp-G and Prsp-C treatments respectively. Percentages of clover lamina-petiole followed a similar pattern in both periods ($p<0.1$ in Period 2). Also percentage grass was affected by a significant interaction of pre-species x species x sward height category ($p<0.05$ in Period 2).

3.4.4. Diet selected.

3.4.4.1. Botanical composition of the ingested diet.

The composition of the diet in terms of the nine botanical components selected by oesophageally fistulated animals on two occasions (Period 2 and 3) in Phase 2 are given in Tables 3.21 and 3.22 for sheep and goats respectively. The overall percentages of grass and clover components in the diet are given in Table 3.23.

Figure 3.22. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species on the 'sward surface' divided into three sward height categories: short (S), medium (M) and tall (T) grazed by sheep (Sp-S) or goats (Sp-G) in Phase 2 (Periods 2 and 3) after have been grazed by sheep (Prsp-S) in Phase 1. For comparison, the data from Period 1 is also given.

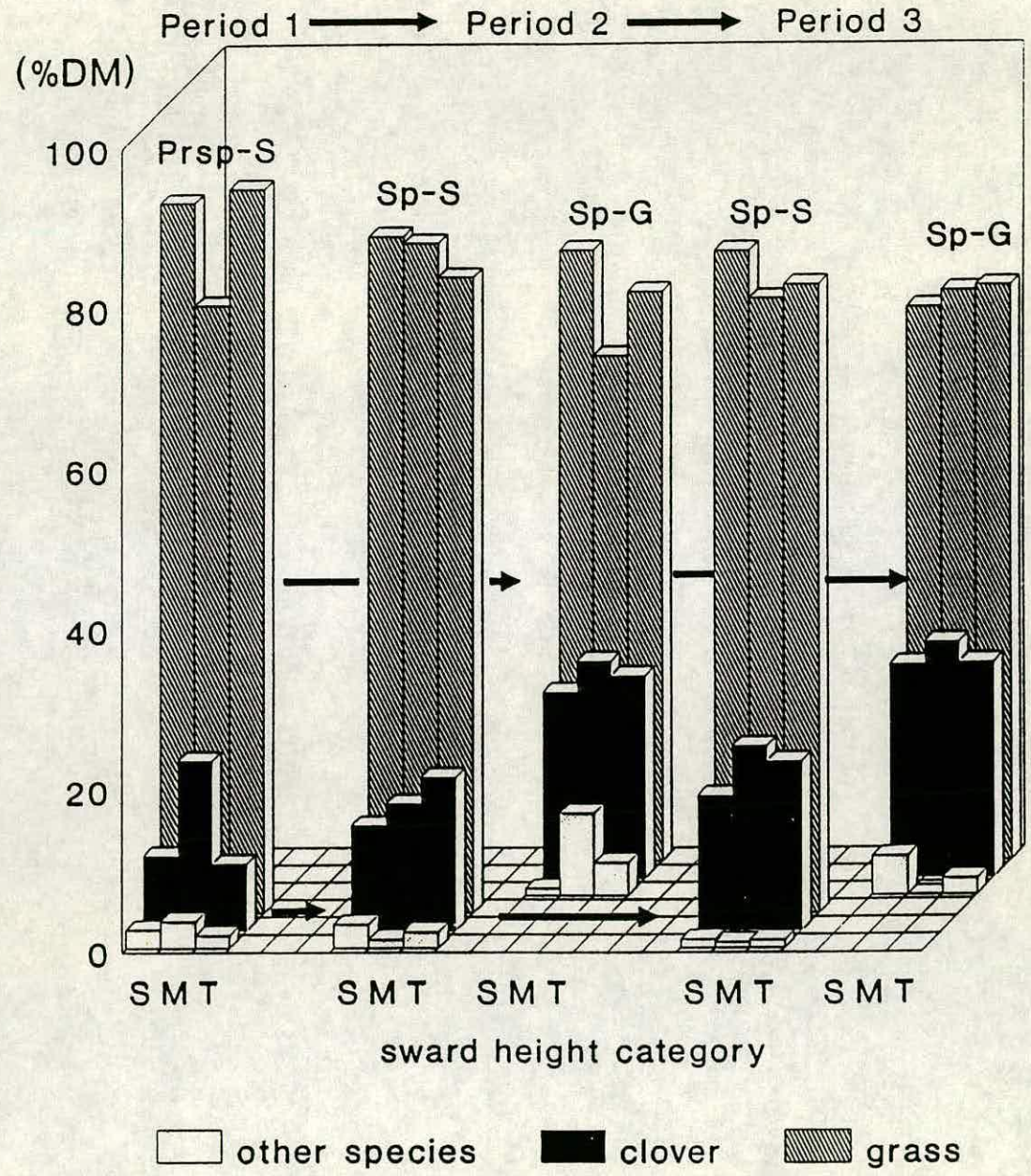


Figure 3.23. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species on the 'sward surface' divided into three sward height categories: short (S), medium (M) and tall (T) grazed either by sheep (Sp-S) or goats (Sp-G) in Phase 2 (Periods 2 and 3) after have been grazed by goats in Phase 1. For comparison, the data from Period 1 is also given.

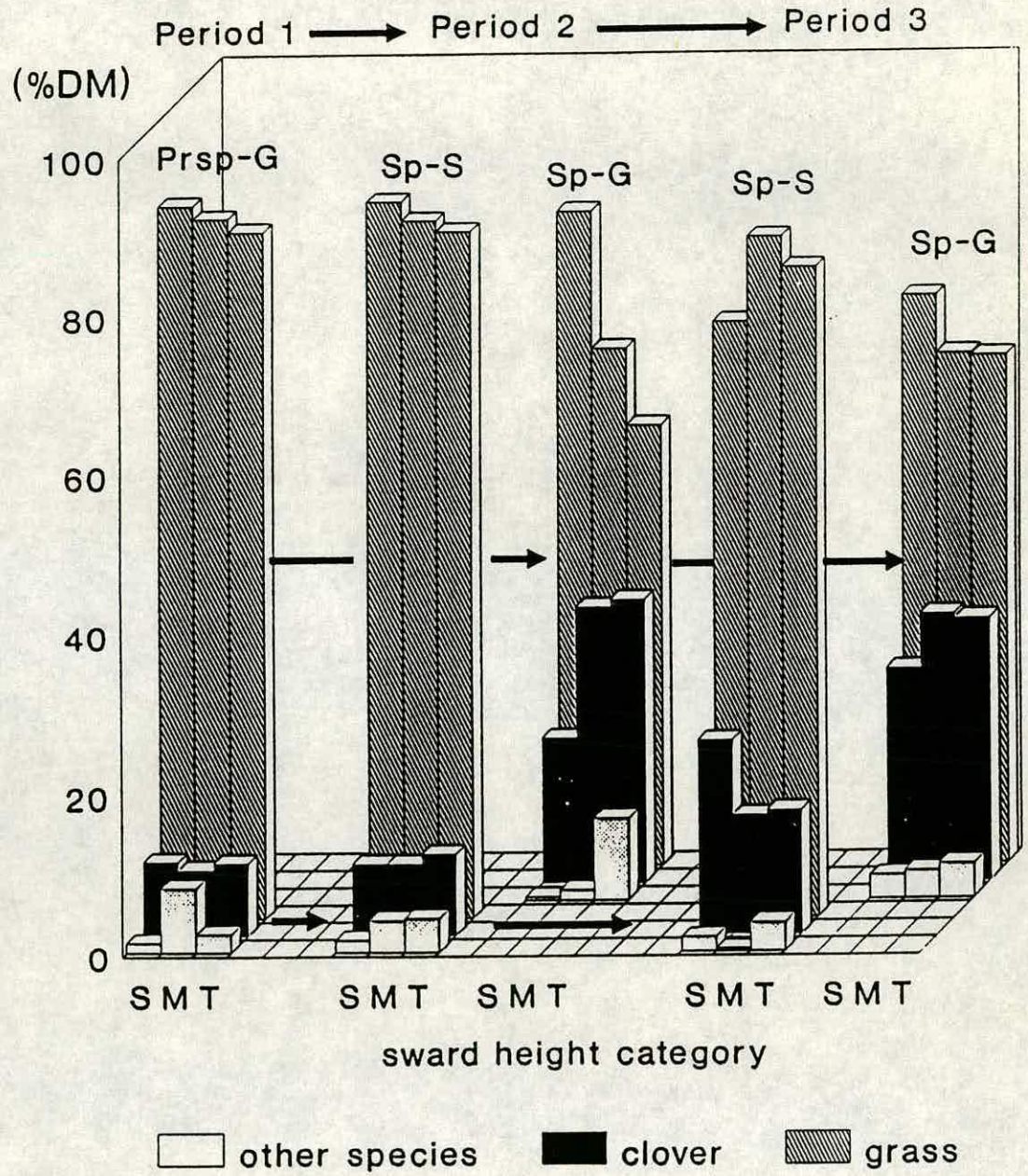


Figure 3.24. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species on the 'sward surface' divided into three sward height categories: short (S), medium (M) and tall (T) grazed either by sheep (Sp-S) or goats (Sp-G) in Phase 2 (Periods 2 and 3) after have been grazed by cattle (Prsp-C) in Phase 1. For comparison, the data from Period 1 is also given.

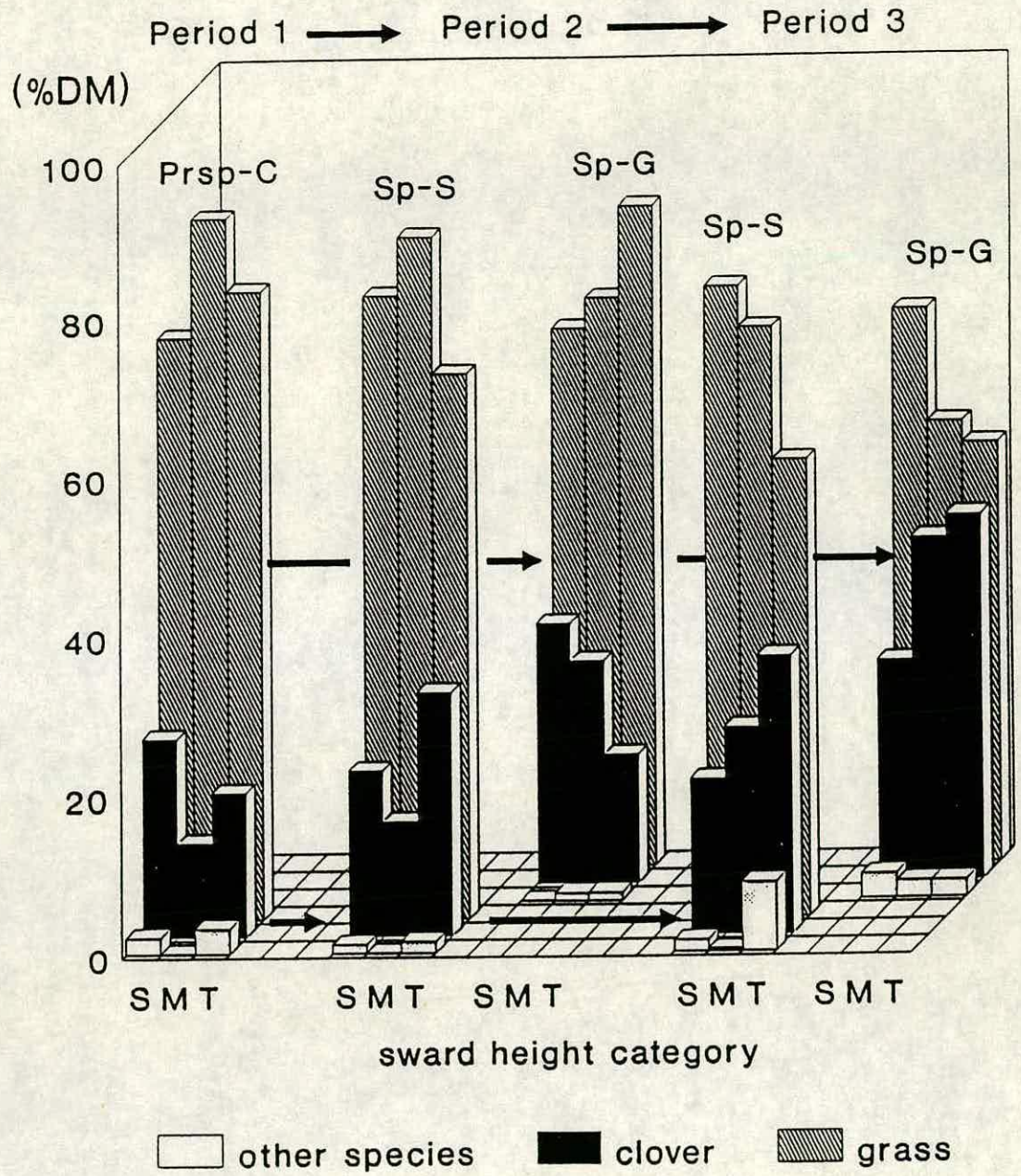


Table 3.21. Botanical composition of the diet (%DM) selected by oesophageally fistulated sheep in Periods 2 and 3 in Phase 2 (n = 6).

Component	Period (Pe)	Animal pre-species in Phase 1 (Prsp)			sed	Level of significance		
		Sheep	Goat	Cattle		Prsp	Pe	Prsp x Pe
Grass leaf	2	64.6	65.1	51.1				
	3	69.9	60.0	52.7	$3.52^{a}/3.55^{b}$	***	ns	ns
Grass pseudostem	2	1.7	2.2	2.9				
	3	1.5	1.5	2.9	$0.45^{a}/0.45^{b}$	***	ns	ns
Grass flowerstem	2	12.4	9.2	7.2				
	3	6.7	6.9	6.4	$2.05^{a}/2.21^{b}$	ns	*	ns
Dead grass	2	7.0	12.2	7.3				
	3	5.9	10.1	6.9	$1.36^{a}/1.47^{b}$	***	ns	ns
Clover lamina-petiole	2	12.4	8.3	28.2				
	3	13.4	15.7	28.0	$2.73^{a}/2.44^{b}$	***	p=0.059	p=0.079
Clover stolon	2	0.03	0.2	1.0				
	3	0.4	0.4	1.0	$0.43^{a}/0.41^{b}$	*	ns	ns
Clover flower	2	0.2	0.03	0.6				
	3	0.03	0.02	0.2	$0.18^{a}/0.18^{b}$	*	ns	ns
Dead clover	2	0.2	0.2	0.2				
	3	0.1	0.5	0.2	$0.16^{a}/0.15^{b}$	ns	ns	ns
Other species	2	0.2	0.8	0.2				
	3	0.6	0.2	0.1	$0.31^{a}/0.30^{b}$	ns	ns	p=0.099

(^{a}- sed. of means with different pre-species level ^{b}- sed. of means with same pre-species level).

Table 3.22. Botanical composition of the diet (%DM) selected by oesophageally fistulated goats in Periods 2 and 3 in Phase 2 (n = 6).

Component	Period	Animal pre-species in Phase 1			sed	p
		Sheep	Goat	Cattle		
Grass leaf	2	63.3	67.7	62.6	8.59	ns
	3	77.9	69.8	72.9	3.87	ns
Grass pseudostem	2	1.0	1.9	1.8	0.55	ns
	3	1.4	2.0	2.2	0.45	ns
Grass flowerstem	2	6.4	4.3	5.6	1.55	ns
	3	3.8	3.7	4.1	0.80	ns
Dead grass	2	8.0	4.0	4.1	1.29	*
	3	5.3	4.8	8.3	1.40	p=0.067
Clover lamina-petiole	2	17.7	19.5	22.4	7.96	ns
	3	9.2	17.3	9.3	3.34	p=0.057
Clover stolon	2	0.4	0.0	0.6	0.50	ns
	3	0.03	0.0	0.3	0.15	ns
Clover flower	2	0.4	0.6	1.5	0.53	ns
	3	0.0	0.0	0.02	0.01	ns
Dead clover	2	0.2	0.3	0.4	0.15	ns
	3	0.2	0.2	0.2	0.11	ns
Other species	2	0.6	0.9	0.3	0.67	ns
	3	0.0	0.1	0.02	0.07	ns

Table 3.23. Total grass and clover (live + dead) in the diet (% DM) selected by oesophageally fistulated sheep and goats in Periods 2 and 3 (n = 6).

Pre-species		Sheep		Goat		Cattle		
Species		Sheep	Goat	Sheep	Goat	Sheep	Goat	sed.[+]
	Period							
Grass	2	85.8	78.7	88.8	77.8	68.5	74.1	6.40
	3	84.1	88.5	78.3	80.3	68.8[a]	87.5[b]	3.32
Clover	2	12.8	18.7	8.7	20.4	29.9	24.8	6.26
	3	13.9	9.4	16.5	17.5	29.4[a]	9.8[b]	3.11

- means on the same grazing period and within a pre-species treatment with different superscripts differ significantly ($p<0.001$).

[+] - from a pooled standard error of differences of the means between species treatments within a pre-species treatment per grazing period (d.f. = 40).

3.4.4.1.1. *Sheep - effect of previous species of grazer.*

The total clover content of extrusa samples from sheep was significantly different between pre-species treatments with 29.7%, 12.6% and 13.3% (sed. 2.08; $p<0.001$) clover dry matter in the diet of sheep following cattle (Prsp-C), goats (Prsp-G) and sheep (Prsp-S) respectively (see Table 3.23). The diet selected by sheep from Prsp-G treatment showed an increased in clover from 8.7% in Period 2 to 16.5% in Period 3 (sed. 2.61; $p<0.01$) while there were no significant changes between Period 2 and 3 on Prsp-S and Prsp-C treatments. Since clover lamina-petiole accounted for almost all the clover eaten (see Table 3.21) not surprisingly, differences in total clover content were reflected in clover lamina-petiole content. Clover lamina-petiole was highest in the diet of sheep on Prsp-C plots than on Prsp-S and Prsp-G plots (28.1% versus 12.9% and 12.0% respectively; sed. 2.12; $p<0.001$). Also, the proportion of clover lamina-petiole selected from Prsp-G plots was lower in Period 2 than in Period 3 (8.3% versus 15.7%; sed. 2.44; $p<0.001$). Although only present in the diet in small quantities, clover stolon and clover flower were selected in higher percentages ($p<0.05$) when cattle was the pre-species than when sheep or goats where the pre-species. No differences between pre-species and between periods were recorded for the low percentages of dead clover selected.

Since grass and clover accounted for over 97% of the diet, differences in the proportion of clover are reflected in the proportion of grass in the diet. The diet selected by sheep differed in the percentage of grass between pre-species treatment: 68.6%, 84.9% and 83.6% (sed. 1.95; $p<0.001$) from Prsp-C, Prsp-S and Prsp-G treatments respectively. As the proportion of clover in the diet

increased between Periods 2 and 3 on the Prsp-G treatment, the percentage of grass selected decreased from 88.8% in Period 2 to 78.3% in Period 3 (sed. 2.62; $p<0.05$). Grass leaf (which accounted for 50-70% of the diet) was eaten in higher proportions from Prsp-S and Prsp-G treatments (67.3% and 62.6% respectively) than from Prsp-C treatment (51.9%; sed. 2.47; $p<0.001$). In contrast, higher contents of grass pseudostem were selected by sheep on the Prsp-C treatment (2.9%) than on Prsp-S and Prsp-G ones (1.6% and 1.8% respectively; sed. 0.31; $p<0.001$). There was no significant effect of pre-species treatment on the percentage of grass flowerstems in the diet ingested by sheep. A significant reduction ($p<0.05$) in the percentage of grass flowerstem occurred between Periods 2 and 3 within pre-species: 12.4%, 9.2% and 7.2% in Period 2 versus 6.7%, 6.9% and 6.4% in Period 3 for Prsp-S, Prsp-G and Prsp-C treatments respectively (sed. 2.21; $p<0.05$). Finally, sheep selected higher percentages of dead grass from the Prsp-G treatment (11.2%) than from Prsp-S (6.5%) and from Prsp-C (7.1%) treatments (sed. 0.88; $p<0.001$).

3.4.4.1.2. *Goat - effect of previous species of grazer.*

Goats tended to select more clover from Prsp-C treatment (24.8%) than from Prsp-G (20.4%) and Prsp-S treatments (18.7%; sed. 8.40; ns) in Period 2 (see Table 3.23). In contrast in Period 3, more clover was selected from the Prsp-G treatment (17.5%) than from Prsp-S (9.4%) and Prsp-C treatments (9.8%; sed. 3.40; $p=0.068$). The pattern of selection of clover lamina-petiole was similar (see Table 3.22). The percentages of clover stolon, flower and dead clover selected were all very low and did not differ between pre-species treatments. There was an effect in Period 2 ($p<0.05$) in the selection of dead grass: higher

percentages were consumed from Prsp-S plots (8.0%) than from Prsp-G (4.0%) and Prsp-C plots (4.1%; sed. 1.29) while in Period 3, 8.3% of dead grass was consumed from Prsp-C plot in comparison to 5.3% and 4.8% from Prsp-S and Prsp-G plots respectively (sed. 1.40; p=0.067).

3.4.4.1.3. *Comparison between sheep and goat diets.*

Individual variation between goats in Period 2 was higher than in Period 3. Consequently, standard errors of the differences (sed.) were greater in Period 2 and affected the statistical differences between species.

In Period 2, there was no significant difference between sheep and goats in the percentage of clover in the diet, although goats tended to have higher clover contents on the Prsp-S and Prsp-G treatments. Clover lamina-petiole followed a similar pattern. The diet selected by goats had more clover flower on all three pre-species treatments, especially on the Prsp-C plots (1.5% versus 0.6% for goat and sheep respectively; sed. 0.40; $p<0.05$).

In contrast, in Period 3, sheep selected proportionally more clover than goats on the Prsp-S treatment (13.9% versus 9.4%; sed. 6.6; ns) and on the Prsp-C treatment (29.4% versus 9.8%; sed. 3.11; $p<0.001$) but not on the Prsp-G treatment (16.5% versus 17.5% respectively; sed. 3.11; ns). Also, in Period 3, goats selected much less clover lamina-petiole than sheep on the Prsp-C treatment (9.3% versus 28.0%; sed. 3.05; $p<0.001$) and Prsp-S treatment (9.2% versus 13.4%; sed. 3.05; ns) but there was no difference between species on the Prsp-G treatment (17.3% versus 15.7% respectively; sed. 3.05). They also consumed less clover stolon than sheep on the

Prsp-C treatment (0.3% versus 1% respectively; sed. 0.32; $p<0.05$) and tended to do so on Prsp-S and Prsp-G treatments. Goats selected less dead clover on the Prsp-G treatment (0.2% versus 0.5%; sed. 0.14; $p<0.05$).

In Period 2, there was no significant difference in the percentage of grass in the diet of sheep and goats. On the Prsp-C treatment, goats tended to select more grass leaf than sheep (62.6% versus 51.1%; sed. 6.57; $p<0.1$) and selected less grass pseudostem (1.8% versus 2.9%; sed. 0.50; $p<0.05$). Goats selected less grass flowerstems than sheep (6.4% versus 12.4%; sed. 1.82; $p<0.01$) on Prsp-S and Prsp-G treatments (4.3% versus 9.2%; sed. 1.82; $p<0.05$) and less dead grass (4.0% versus 12.2%; sed. 1.33; $p<0.001$) on the Prsp-G treatment.

Finally in Period 3 on the Prsp-C treatment, in comparison to sheep, goats had higher percentages of grass ($p<0.001$) and grass leaf ($p<0.001$) in their diet. On both Prsp-S and Prsp-G treatments, goats also selected more grass leaf than sheep: 77.9% versus 59.9% (sed. 3.70; $p<0.001$) on Prsp-S and 69.8% versus 60.0% (sed. 3.70; $p<0.05$) on Prsp-G treatment, but less grass flowerstems ($p<0.1$ on Prsp-S treatment and $p<0.05$ on Prsp-G treatment) and less dead grass ($p<0.001$ on Prsp-G treatment).

3.4.4.2. Digestibility of diet selected.

The digestibility of the diet selected by oesophageally fistulated sheep and goats is shown in Table 3.24. Oesophageally fistulated sheep selected a diet from Prsp-C treatment with a higher mean *in vitro* organic matter digestibility (0.791) than those from Prsp-S (0.775) and Prsp-G (0.758) pregrazed treatment (sed. 0.0078; $p<0.001$).

Table 3.24. Mean *in vitro* organic matter digestibility (proportion) of diet selected by oesophageally fistulated sheep and goats in Periods 2 and 3 in Phase 2 (n = 6).

Prespecies	Sheep		Goat		Cattle		
Species	Sheep	Goat	Sheep	Goat	Sheep	Goat	sed.[+]
Period							
2	0.774	0.772	0.760	0.771	0.793	0.802	0.099
3	0.777	0.781	0.755[a]	0.798[b]	0.789	0.778	0.140

- means on the same grazing period and within a pre-species treatment with different superscripts differ significantly ($p<0.01$).

[+] - from a pooled standard error of differences of the means between species treatments within a pre-species treatment per grazing period (d.f. = 40).

No significative differences were recorded between sampling periods.

Oesophageally fistulated goats also selected a diet of higher digestibility from Prsp-C paddocks (0.802) than from Prsp-S (0.772) and Prsp-G paddocks (0.771; sed. 0.0104; $p<0.05$) in Period 2 while in Period 3 there was no significant difference.

The only significant difference in *in vitro* organic matter digestibility between species was found on the Prsp-G paddock in Period 3, where goats selected a diet with a higher digestibility than sheep (0.798 versus 0.755; sed. 0.0099; $p<0.001$).

3.4.5. Relationships between diet selected and sward composition.

Regression analyses were carried out between the percentage clover selected by oesophageally fistulated sheep and goats during Phase 2 (Periods 2 and 3) and the percentage of clover in both the whole sward and on the sward surface. The effect of pre-species treatment and sampling period on these regressions was also examined.

Positive but non-significant correlations were found between the percentage of clover eaten by sheep and the percentage of clover in the whole sward ($r=0.515$; $n=12$) and on the sward surface ($r=0.386$; $n=12$)(see Table 3.25). Thus, while sheep tended to eat more clover when its presence increased either in the whole sward or on the sward surface, the correlation coefficients between the clover eaten by goats and the clover in the whole sward and on the sward surface were negative ($r=-0.489$ and $r=-0.261$ respectively; $n=12$; see Table 3.26).

Table 3.25. Correlation matrix for percentage of clover in the diet selected by sheep and the percentage clover in the whole sward, on the sward surface and in their respectively height categories (short, medium and tall; n=12).

diet								
1.000								
sward								
0.515	1.000							
surface								
0.386	0.968***	1.000						
short								
sward								
0.501	0.767**	0.757**	1.000					
medium								
sward								
0.184	0.847***	0.827***	0.539	1.000				
tall								
sward								
0.567*	0.927***	0.884***	0.556	0.686**	1.000			
short								
surface								
0.448	0.613*	0.638*	0.931***	0.279	0.462	1.000		
medium								
surface								
0.037	0.733**	0.750**	0.439	0.953***	0.566	0.193	1.000	
tall								
surface								
0.445	0.947***	0.968***	0.658*	0.801**	0.913***	0.522	0.705*	1.000

diet	sward	surface	short	medium	tall	short	medium	tall
			sward			surface		

Table 3.26. Correlation matrix for percentage of clover in the diet selected by goats and the percentage clover in the whole sward, on the sward surface and in their respectively height categories (short, medium and tall; n=12).

diet								
1.000								
sward								
-0.489	1.000							
surface								
-0.261	0.823***	1.000						
short								
sward								
-0.201	0.704**	0.586*	1.000					
medium								
sward								
-0.393	0.863***	0.711**	0.468	1.000				
tall								
sward								
-0.530	0.934***	0.767***	0.522	0.708***	1.000			
short								
surface								
0.153	0.260	0.471	0.697*	0.133	0.052	1.000		
medium								
surface								
-0.072	0.671*	0.615*	0.335	0.805**	0.560*	-0.029	1.000	
tall								
surface								
-0.428	0.863***	0.913***	0.418	0.762**	0.889***	0.130	0.662*	1.000

diet	sward	surface	short	medium	tall	short	medium	tall
			sward			surface		

Therefore, goats tended to eat less clover when its amount increased either in the sward or on the sward surface. Although pre-species treatment had an effect on the percentage clover in the diet of sheep (but not in goats), its addition as an independent variable in a multiple linear regression did not significantly improve the probability of the partial regression coefficients for the percentage of clover in the whole sward or on the sward surface. Introducing sampling period as a explanatory factor also did not significantly improve the fit of the regression in either animal species.

The percentage clover in the diet was subsequently regressed on percentage of clover recorded on short, medium and tall sward height categories in the sward and on the sward surface respectively. Tables 3.25 and 3.26 show the correlation coefficients between these variables.

For sheep, the percentage of clover in the diet was more closely related to percentage of clover in tall sward height category (R^2=0.322; p=0.054) than for any other category or for the sward as a whole. The same was true for goats but the correlation was negative (R^2=0.281; p=0.076).

Also percentage of clover in the diet was more closely related to percentage of clover in the short sward surface height category for sheep (R^2=0.201; ns) and with percentage of clover in the tall sward surface height category for goats (R^2=0.183; ns) than for other sward surface height categories but none of the regressions were significant. Combinations of percentage clover in the whole sward and on sward surface height categories did not significantly increased the variation explained.

When percentage of clover in the diet was regressed

with digestibility of the diet they were strongly related in the case of sheep (R^2=0.649; $p<0.01$):

$$y = -353\ (\pm\ 86.4) + 480\ (\pm\ 111.0)\ \text{digestibility}$$

where y = clover in the diet (%DM).
digestibility = organic matter digestibility of diet (proportion)

(Equation 3.1)

but not in goats (R^2=0.056; ns). Furthermore, diet organic matter digestibility was not significant related with the percentage of clover present in the whole sward or on the sward surface.

Finally, the percentage of clover in the diet selected by sheep was significantly related to a linear combination of diet digestibility and percentage clover in the whole sward and on the sward surface (R^2=0.873; $p<0.001$):

$$y = -302\ (\pm\ 60.0) + 400\ (\pm\ 78.7)\ \text{digestibility} + 3.47\ (\pm\ 1.02)\ \text{sward} - 1.57\ (\pm\ 0.55)\ \text{surface}$$

where y = clover in the diet (%DM).
digestibility = organic matter digestibility of diet (proportion)
sward = clover in the whole sward (%DM).
surface = clover on the sward surface (%DM).

(Equation 3.2)

The equivalent relationship for goats was not significant (R^2=0.428; ns):

$$y = -103\ (\pm\ 95.9) - 1.3\ (\pm\ 0.60)\ \text{sward} + 161\ (\pm\ 121.0)\ \text{digestibility} + 0.6\ (\pm\ 0.45)\ \text{surface}$$

where y = clover in the diet (%DM).
digestibility = organic matter digestibility of diet (proportion)
sward = clover in the whole sward (%DM).
surface = clover on the sward surface (%DM).

(Equation 3.3)

3.5. Discussion.

Firstly, in this section, the variation in sward composition through Experiment 1 is considered in relation to season (Section 3.5.1), sward surface height (Section 3.5.2) and herbage mass (Section 3.5.3). Following that, the results are considered within the framework of the existing knowledge on grazing animal behaviour responses to changes in sward structure and the effects of sward structure on the diet selected (Section 3.5.4.1) and of diet selection on sward composition (Section 3.5.4.2) are discussed. Descriptions of the grazing strategies followed respectively by sheep and goats are proposed in Sections 3.5.5 and 3.5.6. Finally, Section 3.5.7 summarizes the main results for Experiment 1.

3.5.1. Seasonal effect on the sward.

The steady increase in clover mass throughout the experiment (373, 382 and 429 kg DM/ha in Periods 1, 2 and 3 respectively) was associated with a decline in mass of grass (3252, 2785 and 1944 kg DM/ha in Periods 1, 2 and 3 respectively). This was probably due to the low temperatures in May (below 15 °C) when white clover may have had a lower rate of growth than grass. This does not favour white clover because the lower position of their leaves in the canopy results in them being shaded by larger grass tillers (Marriott and Grant, 1990). Clover stolon branching rate was probably also lower at this time as found by Barthram and Grant (1994) working in the same environmental conditions. As temperature increased in June, white clover probably had a higher growth rate than grass and was able to maintain a higher position in the canopy during Phase 2 (Marriott and Grant, 1990).

3.5.2. Sward height heterogeneity.

Comparisons of the effects of grazing by different animal species on sown swards is often confounded by differences in sward height. To avoid this a mean target sward height of 6 cm was selected for the three species. This sward height is recommended by Maxwell and Treacher (1987) for sheep as an optimum for animal output per hectare and also by Merchant and Riach (1994) as a reasonable minimum for goats, although for beef cattle Wright and Whyte (1989) reported an optimum sward height of 9 cm. Furthermore Orr *et al.* (1988) suggested that maintaining the sward at above 6 cm when continuously stocked by sheep led to a greater expression of

reproductive development in the grass (elongated stems) which would lead to a long-term deterioration in sward structure. Thus a sward height of 6 cm was chosen as a compromise height which would maintain the sward in a vegetative state when grazed by all three animal species.

The aim of controlling the average sward surface height inside the range 6 $\pm$ 0.5 cm by regular adjustments of animal numbers was successfully achieved. Therefore it was possible to compare the effects of grazing by cattle, sheep and goats on variability in sward surface height. There was a more skewed distribution of sward surface height on the Prsp-C (cattle-grazed) and Prsp-G (goat-grazed) treatments than on the Prsp-S treatment (sheep-grazed) during Phase 1 and on the Sp-G treatment (goat-grazed) than on the Sp-S treatment (sheep-grazed) during Phase 2. The more skewed distribution was associated with a patchy visual appearance in the cattle-grazed swards, as has been seen by previous authors (Gibb and Ridout, 1986 and 1988; Illius *et al.* 1987; Wright and Whyte, 1989; Gibb, 1991). As Forbes (1982) suggested, cattle may avoid taller patches of vegetation because they have been contaminated through urination and defecation possibly because, as Bazely (1990) pointed out, on these taller patches, the ratio of nitrogen and phosphorus to other nutrients is greater and lower respectively than on other areas of the sward.

At the end of Phase 1 (Period 1), the mean height of the three sward height categories (these being a consequence of arbitrarily dividing the sward samples into three) differed across animal pre-species treatments, suggesting that the frequency or severity of defoliation of these sward height categories was different on each treatment. The short and medium sward height categories were taller (approximately +0.5 cm) on the goat-grazed

paddocks (Prsp-G) than on the sheep- (Prsp-S) and cattle- (Prsp-C) grazed paddocks while the tall sward height categories were approximately +1 cm taller on the goat- and cattle- grazed paddocks than on the sheep-grazed paddocks. Clark *et al.* (unpublished data, cited by Illius and Gordon 1993), found that the short-term intake rate of goats was more sensitive to sward height than cattle and sheep with goats taking shallower bites from a perennial ryegrass monoculture than the other species, especially on taller swards. This could explain why the goat treatments (Prsp-G and Sp-G) had a more uneven sward surface height distribution than sheep. Black and Kenney (1984) recorded that, in contrast to cattle, sheep selected taller areas of ryegrass created by nutrient inputs from sheep urine and faeces and, furthermore, Forbes (1982) observed that sheep were more tolerant than cattle to their own fouled grazing areas. This could explain the more even distribution of sward heights on the sheep-grazed paddocks. Although Illius, Clark and Hodgson (1992) showed by regression analysis that sheep preferred to select taller patches from ryegrass/clover swards grown in seed trays, this contradicts other observations that sheep prefer to graze on shorter vegetation (Arnold and Dudzinski, 1978; Van Soest, 1982) but this may be related to avoidance of material with lower digestibility.

The differences in sward height heterogeneity created by the pre-species treatments at the end of Phase 1 were in turn modified by the subsequent grazing by sheep or goats during Phase 2, although the differences in height between sward height categories due to pre-species in Phase 1 remained during Phase 2.

Although Gibb and Ridout (1986 and 1988) managed to fit double normal distributions to their sward height measurements collected under cattle grazing and postulated

that the two parts of the distribution corresponded to 'frequently grazed' and 'infrequently grazed' components, a binomial distribution of sward heights was not seen in this experiment. This may have been due to the fewer number of measurements of sward height: 50 measurements per plot twice per week as opposed to 150 or 250 measurements per plot three times per week recorded by Gibb and Ridout (1986 and 1988 respectively). Therefore, it may be necessary to carry out more sward surface height measurements to achieve a better representation of the total area occupied by the 'frequently' and 'infrequently' grazed areas in each paddock/plot. In monocultures of ryegrass or white clover continuously stocked with sheep at 6 cm, Penning *et al.* (1991b) found that sward heights for the grass sward were normally distributed while in the clover sward there was a combination of two normal distributions representing recently grazed and ungrazed areas. They suggested that sheep grazing the clover sward may not have been constrained by the decline in sward height as adequate areas of herbage not recently grazed remained.

These data cannot offer a total explanation for the differential variability in sward height across the pre-species and species treatments without a complementary study of the bite weight and intake rate of the grazing animals and also an understanding of the mechanics behind the dynamics and spatial distribution of these grazing bites and a knowledge of the determinants of choice of grazing location (selected patches) as suggested by Demment and Laca (1993), although it can be deduced that the swards showed a different degree of heterogeneity in height as a consequence of some aspects of feeding behaviour.

3.5.3. Herbage mass.

Herbage mass declined slightly from 3625 kg DM/ha in Period 1 to 3167 kg DM/ha in Period 2 and more markedly to 2373 kg DM/ha in Period 3 as the sward density probably declined at the end of Phase 2. As mentioned before, maintaining the sward surface height at 6 cm in a continuously stocking regime avoided excessive reproductive development which would occur under an infrequent cutting regime and would probably result in a larger decline in herbage mass (Orr *et al.*, 1988). As the OM diet digestibility of sheep and goats was relatively high across treatments during Phase 2 this could be accounted for the fact that the swards remained in a vegetative state (high percentages of green material) until the end of the experiment.

The trend of a higher DM herbage mass at the end of Phase 1 in the Prsp-G treatment (3917 kg DM/ha) in contrast to the Prsp-S (3511 kg DM/ha) and to the Prsp-C (3448 kg DM/ha) treatments may be related to the goats' browsing habits of grazing the upper layers of the sward (see Section 3.5.4) and therefore allowing significant higher grass masses to develop in the bottom horizon (0-2 cm) of the Prsp-G sward than in the Prsp-S and Prsp-C swards (2822 versus 2495 and 2269 kg/ha respectively; $p<0.05$). At the end of Phase 2, however, there was only slightly higher DM herbage masses in the goat-grazed (Sp-G) treatment (2464 kg DM/ha) than in the sheep-grazed (Sp-S) treatment (2282 kg DM/ha) although higher clover masses were present in the Sp-G plots than in the Sp-S plots (547 kg DM/ha versus 311 kg DM/ha; $p<0.05$) at the end of the experiment. Associated with this greater decline of herbage mass on swards previously grazed by sheep and cattle than previously grazed by goats, sheep and goat stocking densities were

higher during Phase 2 on plots previously grazed by goats (Prsp-G) than these previously grazed by sheep (Prsp-S) and by cattle (Prsp-C).

Furthermore, the grass mass was lower in the Prsp-C:Sp-S treatment than in the rest of the treatments. Sheep grazing swards previously grazed by cattle left swards visually more sparsely tillered and patchy with less overall green grass leaves ($p<0.05$; see Plate 3.3c) than when grazing swards previously grazed by sheep or goats (see Plate 3.3a). As Arosteguy *et al.* (1983) suggested it may that cattle-grazed paddocks require a greater leaf area and mass than denser sheep- and goat- grazed paddocks for the same rate of pasture growth.

3.5.4. Relationship between diet selected and sward composition.

3.5.4.1. Effect of sward structure on diet selection.

Its widely accepted that the clover content in the diet of grazing sheep is considerably higher than that of the sward as a whole. Curll and Wilkins (1980) found that on average, clover content of the diet was greater than that in the herbage on offer. With goats the results are contradictory. There is evidence of a lower proportion of clover in the diets of goats relative to that on offer (Clark *et al.*, 1982; Russell *et al.*, 1983; Radcliffe, 1985) and this could be due to the poor accessibility of clover lamina-petiole within the sward canopy rather than active discrimination although in most of these studies the sward conditions were not well characterized.

Plate 3.3- Swards during Phase 2.

a) sheep grazing following sheep in Phase 1.
(treatment Prsp-S:Sp-S)



b) goat grazing following goats in Phase 1.
(treatment Prsp-G:Sp-G)



c) sheep grazing following cattle in Phase 1.
(treatment Prsp-C:Sp-S)



In this experiment during Phase 2 whereas the swards of sheep- and goat-grazed plots (Sp-S and Sp-G treatments respectively) had an overall percentage clover of 11.9% and 17.9% the overall percentage clover in the diet of sheep and goats were 18.5% and 16.7%, which conflicts with the results of Collins (1989) who reported that both sheep and goats ate a higher proportion of clover than of perennial rygrass on a sown sward. The difference is probably due to the different environmental conditions existing in New Zealand than in the present study. Furthermore, the percentage of clover ingested by sheep and goats both differed between pre-species treatments and between sampling periods (Periods 2 and 3) during the experiment. However the percentage of white clover ingested was not significantly related to the percentage of white clover present in the whole sward. Milne *et al.* (1982) found that the variation in percentage of clover in the diet of grazing sheep could be better explained by the percentage of clover in the grazed horizon than by percentage clover in the sward as a whole. They suggested that the proportion of white clover in the diet can be increased by increasing the proportion of white clover in the sward and by grazing swards when the content of white clover is greatest in the top layers i.e. on the sward surface. In this study, when the percentage of white clover in the whole sward and on the sward surface were added to diet digestibility as explanatory variables for percentage of clover in the diet, it was possible to explain 87.3% of the variation in proportion of clover in the diet of sheep and only 42.8% of the variation in the diet of goats. This suggests that a substantial presence of clover on the sward surface will promote the intake of clover by sheep (positive regression coefficient) but not necessarily by goats (negative regression coefficient; see Equations 3.2 and 3.3).

Sheep selected a diet with a higher proportion of clover and higher digestibility from plots previously grazed by cattle (Prsp-C) than from plots previously grazed by sheep (Prsp-S) or goats (Prsp-G). This matched the higher percentage of clover lamina-petiole in both sampling periods of the Prsp-C sward surface (Figure 3.24) in comparison with the Prsp-G (Figure 3.23) and Prsp-S (Figure 3.22) treatments. Collins (1989) found that sheep grazing with cattle consumed 12% more clover than when grazed alone whereas Clark and Harris (1985) and Parker and McCutcheon (1992) both related higher diet digestibility values in sheep diets when grazing swards with higher percentages of clover. Thus, preference of sheep for white clover was more pronounced where clover availability in relation to sward structure was greater, as suggested by Nicol *et al.* (1987). For instance, the increase in percentage clover ingested by sheep which occurred in the Prsp-G:Sp-S treatment during Phase 2 (Table 3.23) was related to concurrent increases in percentage clover in the whole sward and on the sward surface (see Figures 3.16 and 3.23 respectively).

The lower proportion of variation in percentage clover in the diet explained by Equation 3.3 for goats may be due either to their greater individual animal variation between sampling periods or also to the lack of a relationship between digestibility of the diet selected and percentage of clover ingested. Furthermore, this lack of a significant relationship might reflect shortcomings in the procedure for defining the sward surface in the current experiment. Barthram (1992) showed under similar sward conditions that cutting samples into two layers in 25 locations gave small coefficients of variation between and within plots respectively. As Burlinson (1987) stated the animal is unlikely to relate to the 'mean' sward canopy structure and it may be argued that the stratified clips

should have been confined to the grazed areas rather than that covering both grazed and ungrazed patches. Unless grazing sites were defined and recorded this would be difficult. However, using a sampling procedure similar to that used in the present experiment, Nicol and Collins (1990) working with sheep, goats and cattle and Laca *et al.* (1994a) working with cattle described their experimental swards as layers, simulating the horizontal grazing style of these animals and managed accurately to describe many of the changes in the mass and composition of vertical sward horizons.

Inevitably, as Burlinson (1987) mentioned there is an inherent problem in any grazing situation where the animal is free to walk over the sward. This was confirmed in the present experiment, as changes in botanical components in the sward did not always match with the presence of those components in the diet selected, as Collins (1989) also found with cattle, sheep and goats grazing ryegrass/white clover swards. It is not easy to explain these discrepancies without knowing more about the exact method of grazing by sheep and goats since it is possible that this affects the growth (and decay) of the plants. It might have been an oversimplification to quote a single value for each component on the sward surface as swards may vary greatly from that measured in their spatial arrangement within this calculated surface stratum. It remains a point for speculation as to whether a different technique for describing the spatial arrangement of the botanical components (e.g. point quadrat measurements) would have assisted the interpretation of these results.

In contrast to sheep, the goats' diet had only a slightly higher percentage of clover when grazing on the former Prsp-C paddocks than on the Prsp-S and on the Prsp-G paddocks in Period 2. This may have reflected the similar

percentage of clover available on the sward surface across the different pre-species treatments (see Figures 3.22, 3.23 and 3.24) although the diet selected was significantly more digestible ($p<0.001$) in the former Prsp-C treatment. Since percentage clover in the diet was poorly related with the OM digestibility of the diet, the higher digestibility was related to a lower percentage dead grass consumed from previously cattle-grazed paddocks. Between Periods 2 and 3, the percentage of clover ingested declined markedly on the Prsp-C (-15.0%) and the Prsp-S (-9.3%) treatments whilst the percentage clover in the Prsp-G treatment showed little change (-2.9%) because of its lower overall increase of the percentage clover on the sward surface. This was associated in the Prsp-C:Sp-G treatment with an increase in the percentage of dead grass consumed producing a decrease in the goat's diet digestibility. McCall and Lambert (1987) postulated that goats defoliate pastures from the top downwards in successive layers and, as seen by Hughes (1990), hardly penetrate into the basal horizon. As the present study suggested, the higher percentage of clover ingested by goats, in contrast to other studies, may have been seen due to a greater accessibility of clover lamina-petiole material in the upper layers of the swards (see Plate 3.3b). As the Sp-G treatment allowed more clover to appear on the sward surface than on Sp-S treatment, goats proportionally ate more clover lamina-petiole than sheep on the Prsp-C and on the Prsp-S treatments. However this was not true in Period 3 in the former Prsp-G paddocks as the greater accessibility of clover within each horizon probably favoured higher consumption of clover by sheep than by goats.

The results suggest that the percentage of white clover ingested by sheep and goats in the present experiment was regulated by the interaction of their preferential or non-preferential defoliation strategy with

the relative accessibility of clover within different sward canopy structures. The percentage clover in the tall sward height category was found to be the best predictor of the percentage of clover present in the diet of sheep and goats explaining 32.2% and 20.1% of its variation respectively. Tall sward height categories had higher herbage masses associated with a greater proportion of white clover in the upper horizons and this was apparently related to greater proportions of white clover in the diet of both sheep and goats. There is thus some evidence that sheep and goats were grazing from the tall areas. This is similar to the observations of Clark *et al.* (unpublished data, cited by Illius and Gordon 1993) where both sheep and goats preferred to graze taller swards. But in the short height categories sheep were also selecting for clover (r=0.501) while goats ate small amounts of white clover (r=0.153). This was related to lower masses of grass leaf present in the upper layers (4-6 cm and >6 cm horizons) of the sward of short height categories probably forcing the goats to graze clover. Parsons *et al.* (1994b) suggested that the cost of foraging increases substantially as selectivity increases or as the horizontal or vertical availability of the desired species decreases, and in these short height categories the cost associated with selection against clover by goats may have been too high. Hughes (1990) also suggested that goats could eat more clover under these circumstances because they would need a lower peak bite force for the consumption of clover lamina-petiole than for eating the less accessible grass components.

It can be concluded from these results that the positive or negative discrimination for clover by sheep and goats respectively was modified by the different sward structures present in the plots.

Finally, although Collins (1989) on her work found

that sheep had a higher proportion of grass leaf in their diets than goats, in the current experiment in Period 2, sheep and goats selected a similar percentage of grass leaf in the Prsp-S and Prsp-G treatments whereas on the Prsp-C treatment goats ate a higher percentage of grass leaf (+11.5%). As recorded on the sward surface profiles, the percentage of grass leaf present under goat-grazing (Sp-G) was lower than that under sheep grazing (Sp-S) in the Prsp-S and Prsp-G treatments and may have limited its selection by goats because of their shallow bites (Clark *et al.* unpublished data; cited by Illius and Gordon, 1993) whereas sheep apparently could graze further down into the sward searching within the horizon for higher proportions of green material (grass leaf and clover lamina-petiole components) as suggested by Milne *et al.* (1982). Following this, as swards previously grazed by cattle (the Prsp-C treatment) were more patchy in appearance than those grazed by other pre-species, the goats would be able to eat more grass leaf from these more 'open' sward conditions and therefore have relatively greater ease of access to grass leaf material than from other pre-species treatments. As seen by previous work on mixed goat-cattle grazing regime (Collins, 1989) this meant that goats may have had access to a relatively larger area for grazing when they followed cattle than when they followed sheep or goats.

3.5.4.2. Effect of diet selection on sward composition.

As a consequence of this apparent rejection of clover by goats, there was a trend both in the whole sward and on the sward surface, for higher percentage clover and clover masses to develop on the goat-grazed plots (Sp-G) than on the sheep-grazed plots (Sp-S) in Periods 2 and 3. In both periods greater decreases in clover stolon mass occurred

within the 0-2 cm horizon of the Prsp-S:Sp-S and Prsp-C:Sp-S treatments during Phase 2 (see Figures A1.15 and A1.24) probably related to deeper grazing and removal of clover by sheep than by goats as seen by Curll and Wilkins (1982) with sheep and Bown *et al.* (1989) with sheep and goats in continuously stocking regimes. Also under a rotational grazing regime, Radcliffe *et al.* (1991) reported higher clover contents under goat grazing than under sheep grazing (13.8% versus 7.5%). These differences in percentage clover created between species treatments in Phase 2 were more pronounced on the sward surface than in the whole sward because white clover tends to have a greater proportion of its leaf area in the upper layers of the canopy than does grass (Dennis *et al.*, 1984). As the white clover may be selected in proportion to its accessibility with respect to grass leaf, then its preferential (by sheep) or non preferential defoliation (by goats) of white clover would be reflected in the sward surface of the plots (see Figures 3.22, 3.23 and 3.24). Evidence for the grazing of the sheep and goats being concentrated on the upper layers of the sward in the present experiment comes from the high percentage of live grass (always above 50.0%) and low percentage of dead grass (always below 13.0%) and of grass pseudostem (always below 3.0%) in the diet of both sheep and goats.

The increase in clover under goat grazing in Phase 2 also resulted in increased percentages of dead clover due mainly to an accumulation of uneaten clover material in the 0-2 cm and 2-4 cm horizons (see Figures A1.17 and A1.26). This was also reported by Clark *et al.* (1984) who concluded that under goat grazing, due to apparently rejection of white clover, more dead white clover tissue would enter the soil as plant litter and consequently N losses might be reduced. Also due to this apparently lower removal of white clover material by goats in the upper layers

throughout Phase 2, a higher percentage of clover flowers appeared in the sward surface of the Prsp-G:Sp-G (see Plate 3.3b) and Prsp-C:Sp-G treatments together with greater clover flower masses within the >6 cm horizon of the Prsp-C:Sp-G treatment (see Figures A1.16 and A1.25).

In contrast to Phase 2, differences in percentage of clover between sheep- and goat-grazed swards in Phase 1 were recorded only on the sward surface but not in the whole sward (see Table 3.6). This contrast between Phase 1 and 2 may be due to differences in the differential growth rates between grass and clover at different times of year. If conditions did not favour the growth of clover relative to grass in Phase 1, then reduced selection of clover by goats may not have resulted in increased clover contents in the sward. At the end of Phase 1, the overall percentage of clover in the whole sward tended to be higher in cattle-grazed paddocks than in sheep- and goat- grazed paddocks (11.8% versus 9.5% and 8.8% respectively). This is in agreement with studies with grass/clover swards by Alder *et al.* (1967) and by Briseño de la Hoz and Wilman (1981) who also recorded higher levels of clover in cattle-grazed than in sheep-grazed swards. Wright *et al.* (1992) recorded 11.1% and 13.1% clover in cattle-grazed plots and 7.6% and 4.7% clover in sheep-grazed plots in plots at 4 and 8 cm sward surface heights respectively while Morrison *et al.* (1985) and Clark *et al.* (1985) observed that sheep appeared actively to select clover while cattle did not. A large part of the difference at the end of Phase 1 in clover contents of cattle-grazed swards was due to the fact that there was considerably more clover lamina-petiole in the short and tall sward height categories (21.6%, 9.0% and 17.2% on short, medium and tall height categories respectively) which resulted in a much greater clover lamina-petiole mass in these categories (358, 194 and 405 kg DM/ha on short, medium and tall height categories

respectively; sed. 87.7). On the goat-grazed paddocks the clover lamina-petiole was more evenly distributed (16.9%, 15.0% and 11.7% for short, medium and tall height categories respectively) while on the sheep-grazed paddocks the values were 6.7%, 15.4% and 6.1% respectively. Thus the primary reason for a trend towards higher clover contents of cattle-grazed swards appears to be an increase in clover in the short and taller areas. The taller areas probably equated with the areas of the sward which were infrequently grazed whereas differences in clover content between pre-species treatments of other sward height categories could be due to differences in the method of grazing. It seems that sheep grazed to lower levels in the sward than cattle and goats had the shallowest bites as seen by Clark *et al.* (unpublished data, cited by Illius and Gordon, 1993). Short areas on cattle-grazed paddocks may be less frequently grazed than on sheep-grazed paddocks as fewer number of lower sward surface height measurements recorded on the Prsp-C treatment than on the Prsp-S treatment during Phase 1 suggested (see Figure 3.7). Thus the increase in clover contents under cattle grazing may be as a consequence of larger intervals between defoliation in part of the sward. It is well documented that a larger defoliation interval can result in increment clover contents in grass/clover swards (Frame and Newbould, 1986; Davies, 1992; Frame, 1992).

The clover lamina-petiole material could overtop the grass on the sward surface of goat-grazed swards in contrast to sheep-grazed swards where sheep would graze down into the sward, removing clover lamina-petiole in the intermediate horizons (Collins, 1989) or even near to ground level (Hughes, 1990) depending of the pasture characteristics. The higher number of lower sward surface height hits recorded on the sheep-grazed paddocks in contrast to the goat-grazed paddocks suggest differences

in bite depth. This was also reflected in differences in the percentage clover present both in the whole sward or in the sward surface between sward height categories within pre-species treatments.

Apart from the differences in clover components, differences in ryegrass components between pre-species and species treatments were also of interest during both experimental phases. In general, as the proportion of clover in the diet or sward increases, then the proportion of grass must decrease. Only points which run against this general trend will be discussed.

In the present experiment although both species showed a general non-preference harvesting for dead material in both sampling periods during Phase 2 (Period 2 and 3), sheep ate a significantly higher percentage of dead grass than goats from the Prsp-G treatment. This matched with greater accumulation of dead grass masses in the lowest horizon in goat-grazed paddocks (Prsp-G) than in sheep- (Prsp-S) and cattle- grazed paddocks (Prsp-C) during Periods 1, 2 and 3 (see Figures A1.4, A1.13 and A1.22) associated probably with the inability of goats to graze near the ground level. Goats have a narrower mouth than sheep and cattle and the absence of a tongue-gathering grazing mechanism may be an advantage in avoiding ingestion of dead grass material. Similarly Collins and Nicol (1987) recorded lower percentages of dead material in cattle-grazed swards (39%) than in sheep- (61%) and in goat-grazed swards (49%). Furthermore, Hughes (1990) reported that calves consumed a greater proportion of dead material than kids or lambs and also Nicol *et al.* (1987) recorded a higher apparent discrimination by goats against dead material although Clark *et al.* (1982) found a lower degree of dead grass discrimination on goats than on sheep.

However in Phase 2, sheep-grazed plots (Sp-S) resulted in a higher percentage of dead grass than on goat-grazed plots (Sp-G), mainly confined to the 0-2 cm horizon. As the grass pseudostem content increased this would restrict the sheep grazing depth and consequently would allow a higher accumulation of dead matter near to the ground level (Barthram, 1981). Also, different proportions of grass pseudostem between treatments were seen in Period 1. The overall percentage grass pseudostem was lower in the whole sward in the goat-grazed paddocks than in cattle- and sheep- grazed paddocks ($p<0.001$), especially in the short and tall height categories. For instance, sheep-grazed paddocks (Prsp-S) had higher masses of grass pseudostems in the 0-2 cm horizon of the tall sward height category (839 versus 624 and 565 kg/ha/horizon in the Prsp-S, Prsp-G and Prsp-C treatments respectively). Taken together these results indicate that, although in all the pre-species and species treatments, taller sward height categories had higher percentage of grass pseudostem and flowerstem material than short and medium height categories, overall, swards grazed by goats had a lower percentage of such material because of their inherent browsing habits (Nicol, 1988) allowing the swards to have greater amounts of grass vegetative material. These differences were also seen by Collins and Nicol (1987) who recorded in pastures grazed by cattle higher grass reproductive material than those grazed by sheep and goats (25% versus 16% and 17% respectively).

Finally, there were a trend towards higher masses of other species in the medium and tall height categories in the goat-grazed paddocks than in the sheep- and cattle-grazed paddocks (see Figure A1.9) at the end of Phase 1 and also at the end of Phase 2 especially in the Prsp-G:Sp-G and Prsp-S:Sp-G treatments. This could be due to the production of more taller clover units under goat grazing

than under sheep grazing as seen visually on the field giving a higher potentially enhancement of nitrogen (N) and therefore potential for growth by other competitive plant species. This was also shown by Radcliffe *et al.* (1991) who reported 3.8% and 1.6% weed contents in goat-grazed pastures and sheep-grazed pastures respectively.

3.5.5. Grazing strategy of sheep.

The percentage clover in the diet of sheep was more closely related to the percentage of clover in the whole sward (r=0.515) than to the sward surface (r=0.386). This may indicate that the sheep not only ate the easily accessible clover but grazed down to obtain clover within the sward. Milne *et al* (1982) found that sheep selected for clover at low levels and against clover at high levels in the grazed horizon and Parsons *et al.* (1994b) have suggested that a diet of intermediate clover contents may have greater 'value' to sheep than diets with very high or very low clover content. In the present study sheep consumed proportionally more clover than was present in the sward. Although there was a positive association between diet digestibility and the percentage clover in the diet, the sheep did not maximize diet digestibility by selecting a diet of 100% clover. They selected a mixed diet of ryegrass and white clover as in other recent studies of foraging behaviour in sheep (Illius and Gordon, 1990; Illius *et al.*, 1992;, Newman *et al.*, 1992). It might be reasonable to suggest that for the sheep the costs of selecting and eating a pure clover diet and continuously rejecting ryegrass components can outweigh the benefits and so a mixed diet of clover (10-30%) is selected (Thornley *et al.*, 1994). The percentage clover eaten may be not only determined by the clover mass encompassed within a bite but

by the spatial distribution of this clover material in the canopy volume as Burlinson, (1987), Laca *et al.*, (1992a) and Laca *et al.*, (1994a) pointed out. Then it may be that to satisfy their energy requirements sheep perhaps need to graze further down into the sward than goats and as a consequence ingested more clover. All of this suggests that preference of sheep for clover would be more pronounced when its vertical and horizontal accessibility is greater.

3.5.6. Grazing strategy of goats.

The diet selected by goats was more variable than that by sheep. This agrees with the findings of Collins (1989). She proposed that goats would harvest a variable quality of diet with the motive of maximizing the consumption of new growth encompassed by a surface grazing strategy. However the results in the current experiment could be biased because fewer goats were used (three animals) than sheep (six animals).

As Collins (1989) and Hughes (1990) suggested, it might be that unlike sheep, goats are unwilling to graze lower horizons. Goats with their relative narrow incisor breadth, compared to sheep, and absence of a tongue gathering grazing mechanism appear poorly equipped to graze clover in the least dense pasture horizon, that is at the sward surface. The tall and medium sward height categories which had less dense upper horizons than the short height categories probably allowed goats to 'browse', topping the ryegrass and apparently rejecting clover components (McCall and Shaw, 1991) while on the short height categories the goats may have been forced to consume some clover as green

grass availability was reduced. As diet selected by goats were significantly more digestible than diets selected by sheep ($p<0.001$) it could be suggested, as Hughes (1990) concluded in his work, that the grazing strategy of the goat may be one of harvesting plant material of the highest quality in the surface horizon. However although goats ate some white clover in this study it is difficult to reconcile this with the fact that percentage clover in the diet was not related to the OM digestibility of the diet selected. Collins (1989) explained this apparent contradiction by suggesting that goats followed a grazing strategy which allowed them to combine diet quality with a high rate of intake and maintain a wider variety of components in the diet than sheep to reduce the risk of reliance on one feed source. As the accessibility of clover became higher, they ingested more clover. Therefore it is reasonable to suggest that although there was an avoidance of clover, goats might have consumed clover as a consequence of its accessibility interacting with their apparently shallow grazing behaviour, sampling for fresh vegetative material of higher quality. This could explain why goat-grazed swards had a more uniform horizontal distribution of clover through all the horizons than sheep-grazed swards.

3.5.7. Summary.

In this study differences between pre-species treatments on sward surface height distribution and on the vertical arrangement of ryegrass and white clover components across the horizons and sward height categories in which the sward were divided provided a good evidence that cattle, sheep and goats vary in their sensitivity to pasture structure and/or composition. Cattle-grazed swards

tended to have higher proportions and amounts of white clover which was particularly related to the amount of clover in tall areas of the sward. Goats also appear to have a different grazing strategy to sheep. The goat's apparent rejection of white clover reversed the normal effect of grasses shading clovers and together with the heavier losses of clover stolons suffered on the swards grazed by sheep allowed the swards subsequently grazed by goats to have higher clover contents than the swards subsequently grazed by sheep in the whole sward and on the sward surface.

Also differences in the composition of the whole sward and of the sward surface, as measured in the experiment determined to some extent, but not completely the clover ingested by sheep and goats. The pre-species treatment still influenced diet selection even after accounting for whole sward and sward surface composition indicating difficulty in describing sward canopy structure in a way which is completely satisfactory from the point of view of predicting diet composition. However, the proportion of clover present on the sward surface together with that on the whole sward and the digestibility of the diet helped to determine the percentage clover ingested in both animal species although goats showed greater variability in the diets selected. Both animals ingested more clover from tall areas of the sward than from medium and short areas and whereas sheep seemed to graze down within the horizon searching for clover lamina-petiole and grass leaf, goats harvested plant material of the highest quality in the surface layers. More research is required to verify this hypothesis.

CHAPTER 4

EXPERIMENT TWO

The effect of animal species and sward height on the competitive ability of grass and clover and on the subsequent facilitation for weaned lambs.

4.1. Introduction.

The main aim of this experiment was to compare the diet selection, herbage intake and animal performance responses of weaned lambs to variations in the sward structure of grass/clover swards grazed previously by either sheep or goats under different sward height conditions.

The experiment also extends the results of Experiment 1 by incorporating some of the same animal species sequences but at a number of sward heights.

4.2. Materials and methods.

4.2.1. Site and location.

The experimental site was at The Macaulay Land Use Research Institute's Hartwood Research Station in central

Scotland, although in a different field from that used in Experiment 1. Full details of the soil type is given in Section 3.2.1.

The experiment was conducted in 1992. Annual rainfall (January 1992 - December 1992) was 1321 mm (124% of average).

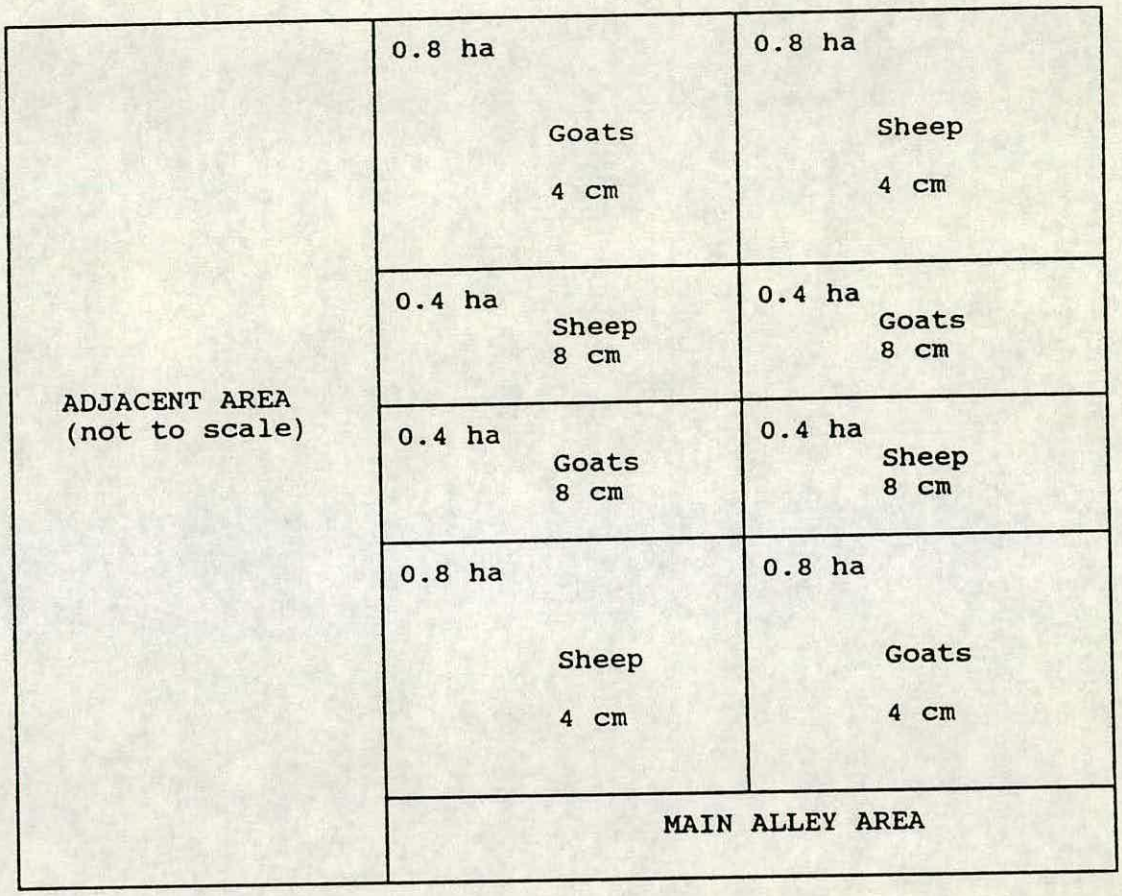
4.2.2. Experimental design.

Ewes and twin lambs or goats continuously grazed ryegrass/clover swards at one of two sward surface height treatments: either at 4 cm (0.8 ha paddock) or at 8 cm sward surface height (0.4 ha paddock) from 26 May to 22 July (Phase 1). Each treatment was replicated twice so that there were eight paddocks (see Figure 4.1).

On 22 July the paddocks which had been grazed at the 4 cm sward height were subdivided into two plots of 0.4 ha. The animals were removed from one of each pair of plots while the other continued to be grazed at a sward surface height of 4 cm. Grazing was also continued on the 8 cm treatment paddocks. The swards in the plots with no animals were allowed to increase in height until they reached approximately 8 cm, at which time (12 August) ewes and lambs and goats were removed from the paddocks and all plots were stocked with weaned lambs until 30 September (Phase 2).

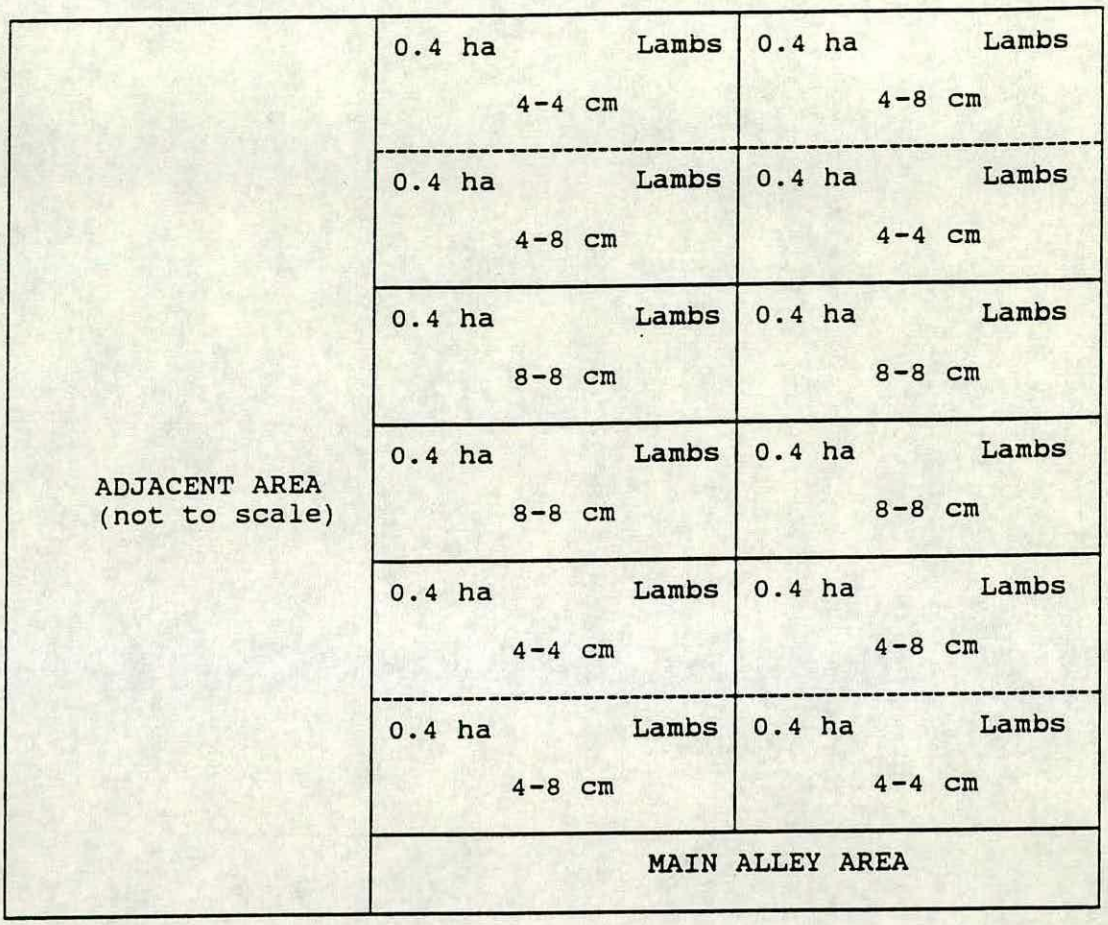
The experiments had a 2 x 3 factorial design, i.e. two animal species (pre-species) in Phase 1 x three sward height treatments (see Figure 4.2).

Figure 4.1- Plan (approximately to scale) of the experimental layout of Phase 1.



_____ Permanent fence erected throughout Phase 1.

Figure 4.2. Plan (approximately to scale) of the experimental layout of Phase 2.



———— Permanent fence erected throughout the experiment (Phase 1 and Phase 2).

---------- Fence erected at the end of Phase 1.

The sward height treatments have been designated 4-4 cm, 4-8 cm and 8-8 cm treatments. As in Experiment 1, the term 'paddock' is used to denote experimental areas in Phase 1 while 'plot' refers to experimental areas in Phase 2.

4.2.3. Sward.

The experimental sward was sown on 24 May 1990 with 30.5 kg/ha of a mixture of perennial ryegrass and white clover. The varieties sown are shown in Table 4.1.

In the experimental year (1992) the first application of fertiliser, on 5 May, was of 12.3 kg/ha of N and 63 kg/ha of P_2O_5 and 63 kg/ha of K_2O. On 16 July, the sward received another application of 62 kg/ha of P_2O_5 and 62 kg/ha of K_2O.

4.2.4. Animals.

In Phase 1, a 'core' flock of 30 lactating Greyface ewes with twin Suffolk-cross lambs, born between 23 March and 9 April 1992, was used. A 'core' flock of 128 yearling castrated male goats of the same genotypes used in Experiment 1 was also used. They were allocated at random but balanced for live weight between treatments.

An additional 18 Greyface ewes with 36 twin lambs plus 52 yearling castrated male goats from the same sources as the experimental 'core' animals were used to adjust stocking rates to control sward heights during Phase 1.

Table 4.1. Details of re-seeding of swards used in Experiment 2.

Sowing Date	Species	Variety	Seed rate per ha (kg/ha)
24 May 1990	perennial ryegrass	Baranna	6.0
	"	Condesa	6.0
	"	Contender	4.0
	"	Duramo	4.0
	"	Macella	8.0
	white Clover	S184	2.0
	"	Kent Wild White	0.5

In Phase 2 a 'core' of 120 weaned Suffolk x Greyface lambs born between 6 April and 5 May and weaned on 3 August plus an extra 20 weaned lambs from the same flock, ranging in live weight from 27 to 32 kg, were used. They were allocated at random balanced for date of birth, live weight and sex to the treatments.

Six weaned Suffolk x Greyface lambs from the same flock were oesophageally fistulated and used to collect samples of the diet selected.

4.2.5. Management.

The experiment commenced when the paddocks achieved their pre-determined sward surface heights.

Adjustments to stocking rate were carried out as necessary following the measurement of sward height twice weekly. When not grazing the experimental paddocks, animals grazed in a nearby area of the same sward.

During both phases of the experiment, animals were regularly run through a footbath containing a solution of zinc sulphate (100 g/l; Deosan). All animals were drenched against internal parasitic worms with a dose of 0.08% of Ivermectin (Oramec drench, MSD Agvet, UK), before going on pasture and approximately every four weeks, but not during an intake measurement period. Regular checks of feet were carry out on all the animals, especially on goats, during wet periods and hooves were trimmed back, as required.

A mineral lick and water were available to all the animal groups during the experiment. The goats had access to small shelters.

4.2.6. Pasture measurements.

4.2.6.1. Sward height.

Sward surface height was measured twice weekly using an HFRO sward stick (as in Experiment 1). Fifty measurements were recorded at random as the operator followed a 'W' shaped route through each paddock or plot.

4.2.6.2. Pasture composition.

Herbage mass and the vertical distribution of sward components were estimated using the same procedure as in Experiment 1, except that the samples were bulked within horizon from all 24 samples per plot, i.e. the samples were not separated into those from 'short', 'medium' and 'tall' areas, as in Experiment 1.

Thus, four horizon-bulked samples were collected from each plot for the 0 to 2, 2 to 4, 4 to 6 and >6 cm horizons.

Measurements were made three times in Phase 1: at the start (22-26 May), middle (1 and 2 July) and at the end (17-20 July) of this phase. In Phase 2, measurements were also made on three occasions: at the beginning (10 and 11 August), middle (21-28 August) and at the end (18-25 September) of this phase.

Each sample was stored at -20 ^{0}C until, separated

into:

- live grass
- dead grass
- live clover
- dead clover
- other species
- unidentified remainder.

All separated material was washed, oven dried for 24 hours at 80 ^{0}C and weighed. All weights were then corrected to kg DM/ha.

4.2.7. Animal measurements.

4.2.7.1. Live weight and condition score.

All animals were weighed (non-fasted) every two weeks throughout the experiment.

When live weight was measured during Phase 1, body condition score was recorded on ewes on the 0 to 5 scale described by Russel, Doney and Gunn (1969). On goats, body condition was recorded following the procedure described originally by Santucci and Maestrini (1985), Poisot (1988) and according to Russel (1990). All condition scoring was carried out by the same person. Although the condition scoring scale is the same, sheep and goats have a different distribution of fatness in the body: fat is stored subcutaneously in sheep whereas goats store more fat internally (see Appendix 2).

4.2.7.2. Herbage intake.

Herbage intake and diet selection in weaned lambs were measured twice in Phase 2 on one replicate only, at approximately the same time as measurements were made of sward composition.

Herbage DM intake of the 'core' animals was measured using the n-alkane technique developed by Mayes, Lamb and Colgrove, 1986. Alkanes were extracted by a modification (Mayes, unpublished data) of the method of Mayes *et al.* (1986).

On the two measurement occasions in Phase 2, starting on 17 August and on 14 September respectively, the 10 'core' lambs from each plot of one of the replicates were dosed daily for 11 days between 09.00 h and 10.30 h with paper pellets of 1 g impregnated with 99 $\pm$ 1.9 mg C_{28}, C_{32} and C_{36} n-alkanes. Rectal faecal grab samples were collected from each animal once daily at the time of dosing on the last 4 days of each dosing period and on the following day. The faeces samples were bulked within animal and stored at -20 ^{0}C. The samples were then freeze dried and milled through a 1 mm screen prior to analysis for n-alkane content.

During the same measurement periods oesophageally fistulated lambs (see Section to 4.2.7.3.2) provide samples of the diet from the relevant plots for C_{33} alkane determination.

As Dove and Mayes (1991) described, herbage dry matter intake is calculated from the ratio of dotriacontane: tritriacontane (C_{32}:C_{33}) in faeces, the concentration of C_{32} and C_{33} in extrusa and the dose of C_{32} by the following

equation:

$$HI = \frac{(\frac{F_{33}}{F_{32}}) x D_{32}}{H_{33} - (\frac{F_{33}}{F_{32}}) x H_{32}}$$

where: HI = Herbage Intake (kg DM per day)
F_{33} = Faeces C_{33} concentration (mg/kg DM)
H_{33} = Extrusa C_{33} concentration (mg/kg DM)
F_{32} = Faeces C_{32} concentration (mg/kg DM)
H_{32} = Extrusa C_{32} concentration (mg/kg DM)
D_{32} = Pellet C_{32} content (mg/day).

(Equation 4.1)

4.2.7.3. Diet selected.

4.2.7.3.1. *Oesophageal fistulates.*

Six suckling Suffolk x Greyface lambs were oesophageally fistulated on 6 July, six weeks before their use, using the same procedures as described for Experiment 1 except that they were fitted with a 'T' shaped plug from the time of surgery. From 9 July to 3 August, when they were weaned, they grazed with their mothers.

Care and maintenance of the animals followed the same methods as explained in Section 3.2.7.1.1. Animals were rotated around the experimental plots 2 weeks before their use. Training was carried out to familiarise the animals with the collection procedures.

The lambs were used on two occasions: on 21-28 August

and on 18-25 September at the same time that measurements were made of herbage intake and sward composition. In any one day, two samples were collected from each animal from each plot, one in the morning (10.30-11.30 h) and the other in the afternoon (15.30-16.30 h) on the same replicate on which intake was being measured. The collection periods lasted approximately 15 minutes, using the procedures detailed in Section 3.2.7.1.1. The lambs always grazed a plot for at least one day before samples were collected.

4.2.7.3.2. *Botanical composition.*

Extrusa samples were frozen at -20 ^{0}C and subsequently freeze dried. The sample was throughly but gently mixed and a subsample of 10 g of DM mass taken. It was manually separated by the same person into the same components as the sward herbage samples:

- live grass
- dead grass
- live clover
- dead clover
- other species
- unidentified remainder.

The separated material was oven dried (80 ^{0}C) for 24 hours and dry weight recorded.

4.2.7.3.3. *'In vitro' digestibility.*

The remaining portion of the freeze-dried extrusa sample was subsampled (3 g of DM mass), milled through a 1

mm screen and analysed for *in vitro* digestibility by the method of Tilley and Terry (1963) as modified by Alexander and McGowan (1966).

4.2.7.4. Animal health.

To monitor the internal parasite burden, additional faeces samples from 5 'core' lambs/plot were collected at the time of collection of grab samples for n-alkane determination at the end of Phase 2. These rectal faeces samples were stored at 4 ^{0}C prior to subsequent worm egg counts.

4.3. Statistical analysis.

Data was firstly tested for normality and subsequently analysed by using Genstat 5.2 (Lawes Agricultural Trust, 1990). Statistical analyses comprised analysis of variance on each of the sward and animal variables measured plus correlation and regression analyses to investigate relationships between these variables. Minitab 7 (Minitab Inc., 1989) was used to conduct χ^2 tests where appropriate.

4.3.1. Sward height.

Comparisons of the distribution of sward height measurements during Phase 1 and Phase 2 were carried out using the procedure utilised on Experiment 1 (see Section 3.3). Mean sward heights in each phase were compared by analysis of variance where paddocks (Phase 1) or plots

(Phase 2) were used as the blocking factor and replicate, pre-species and sward height treatment (plus the interaction of the last two) were used as the treatment factors.

4.3.2. Sward composition.

For each of the five botanical components of the sward, treatment means were obtained by a similar procedure (a partially hierarchical nested analysis) to that used in Experiment 1. From the raw data the composition of the sward as a whole and of each horizon was calculated. The composition of the 'sward surface' was calculated by a mathematical procedure already explained in Section 3.3. Analyses of variance were then carried out on each of the percentages of the five botanical components and on their respective percentage totals (grass or clover) using replicate, pre-species and sward height treatment (plus the interaction of the last two) as factors and paddock (Phase 1) or plot (Phase 2) as blocking factors. Also the amounts (kg/ha) of the five botanical components and their totals were analysed for each sampling period with replicate, pre-species, sward height treatment and horizon (plus the interaction of the last three) in Phases 1 and 2 and paddock (Phase 1) and plot (Phase 2) as blocking factors. An example of an ANOVA carried out in Phase 2 is given in Appendix 3b.

Finally, the effects of treatment were also tested through both phases with replicate, pre-species, sward height treatment, horizon and sampling period (plus the interaction of the last four) and paddock as a blocking factor in Phase 1 and plot as a blocking factor in Phase 2.

4.3.3. Diet composition.

Diet selection (the proportion of each component and of their totals) and digestibility data from extrusa samples on Phase 2 were analysed by analysis of variance. Data from weaned lambs from both sampling periods were analysed with pre-species, sward height treatment and sampling period (plus their interaction) as treatment factors and animal nested within plot as a blocking factor. Also lamb herbage intake in Phase 2 was analysed using pre-species, sward height treatment and sampling period (plus their interactions) as treatment factors and plot as blocking factors.

4.3.4. Animal performance.

All data recorded on animal responses (live weight, live weight changes, body condition score changes, stocking rate, animal grazing days and total output per hectare) were statistically analysed by using ANOVA with replicate, and sward height treatment factors in Phase 1 and replicate, sward height treatment and pre-species (plus the interaction of the last two) as treatment factors in Phase 2. Ewes' live weights were corrected for the weight of wool clipped after they were sheared during Phase 1. In Phase 1, effects of sex, initial live weight and initial body condition score of goats or sheep were used as covariates but did not show any significant effects. In Phase 2, sex, date of birth, birth weight and initial live weight of the weaned lambs used were used as covariates in all the analyses of variance.

Multiple regression analysis was used to build up

models of variables considered to be important in the response during Phase 2 in the percentage of clover selected on the diet, herbage intake and live weight gain of the weaned lambs in Phase 2 and also on ewe, lamb and goat live weight changes during Phase 1. Sward height treatment and sampling period in Phase 1 and pre-species, sward height treatment and sampling period in Phase 2 were used as explanatory terms and consequently added or dropped depending on whether or not they improved the fit of the regressions.

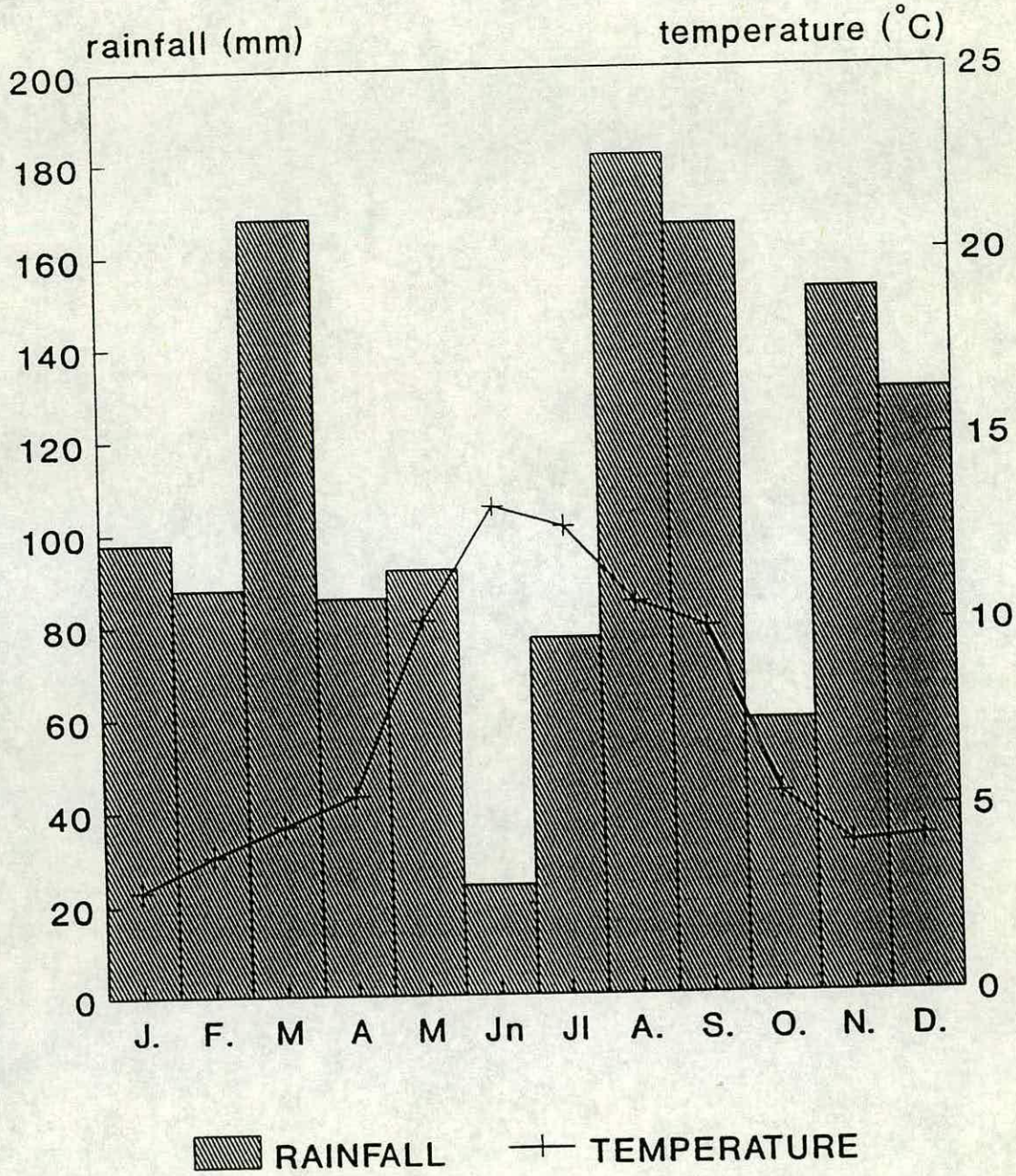
4.4. Results.

In the presentation of results the sheep and goat (pre-species) treatments on Phase 1 are indicated as Prsp-S and Prsp-G respectively while the sward height treatments in Phase 1 are labelled as 4 or 8 cm treatments and in Phase 2 as 4-4 cm and 8-8 cm treatments (swards which were grazed at a height of 4 and 8 cm respectively) and 4-8 cm (swards which were allowed to increase in height from 4 to 8 cm at the start of Phase 2). Proportions of components in the sward and in the diet are expressed as percentage values.

4.4.1. Weather.

Figure 4.3 shows the monthly distribution of rainfall and temperature over the year 1992.

Figure 4.3. Monthly mean temperatures (°C) and rainfall (mm) recorded at the experimental site during 1992.



Although the first dressing of fertiliser was applied in April, the wet weather: 86 mm rainfall (134 % of average) and 5.4 °C mean daily temperature, delayed the turn out of the stock until mid-May when eventually warm and dry weather prevailed (92 mm rainfall and 10.1 °C mean daily temperature). These conditions prevailed through June (24 mm rainfall and 13.2 °C mean daily temperature) and most of July (77 mm rainfall and 12.6 °C mean daily temperature). In marked contrast to the earlier part of the summer, the latter half was very wet with 181 mm (162 % of average) and 166 mm (150 % of average) rainfall in August and in September respectively.

4.4.2. Sward height.

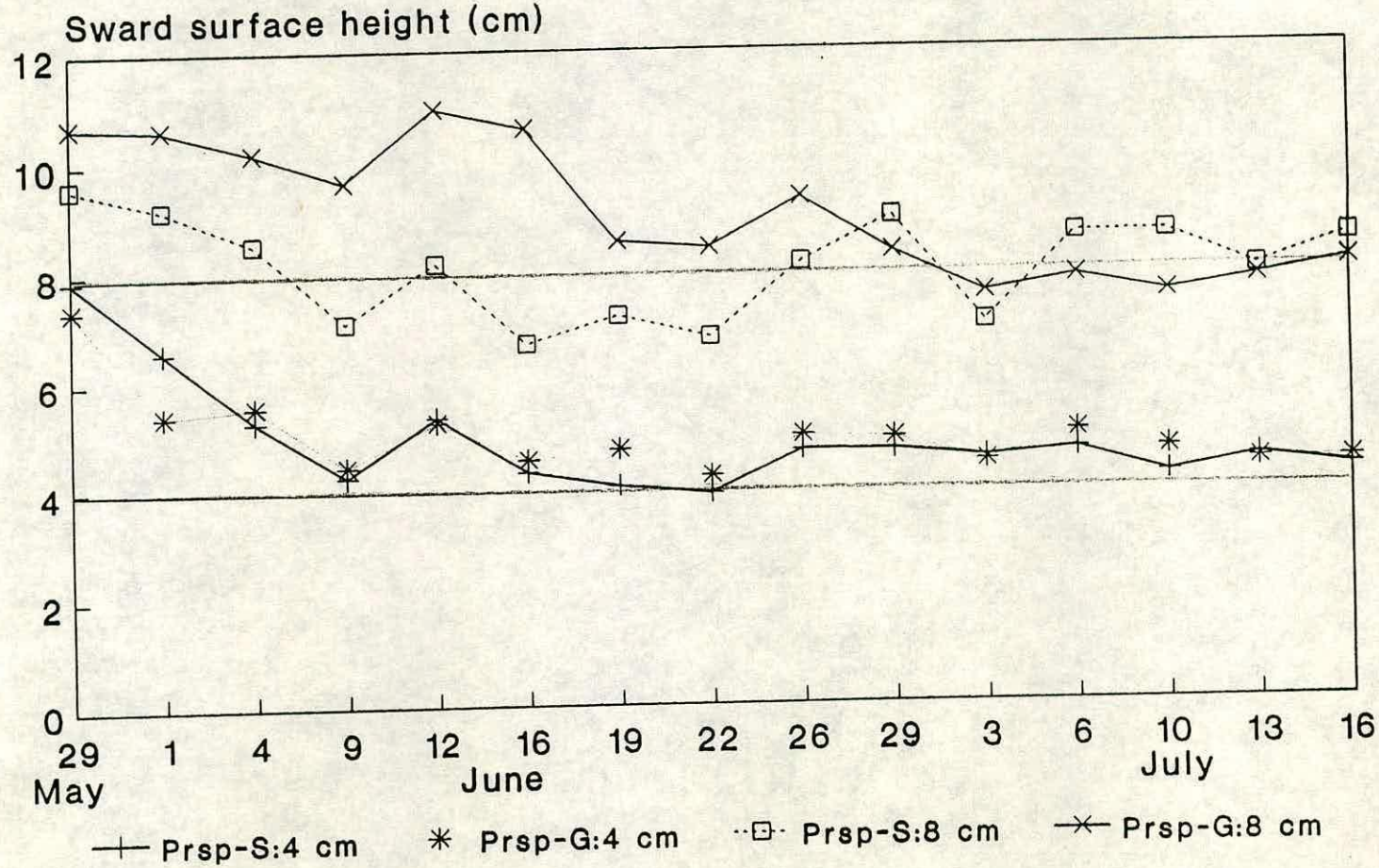
Table 4.2 shows the overall mean sward heights for each treatment in Phase 1 and Figure 4.4 shows the changes in sward height in Phase 1.

Table 4.2. Mean sward surface heights (cm) during Phase 1 (n = 3000).

pre-species	sheep		goat		
Height (cm)	4	8	4	8	sed.
Sward height	4.9	8.1	4.8	9.0	0.50

From 29 May there were initial non-significant differences between pre-species treatments on the 8 cm sward height treatment until 19 June. From this date, Prsp-G paddocks were maintained close to the target sward height of 8 cm which had been achieved by 4 June on the Prsp-S treatment (Figure 4.4).

Figure 4.4. Pattern of change of sward surface heights in Phase 1.



This explains the slightly higher overall mean sward height on Prsp-G paddocks (9.0 cm) than on Prsp-S paddocks (8.1 cm; sed. 0.50; ns) and also resulted in a significant interaction between pre-species x sward height treatment x day of measurement. However, on the 4 cm sward height treatment both pre-species treatments reached the target height on 9 June (see Figure 4.4) and from then showed little deviation from the target height.

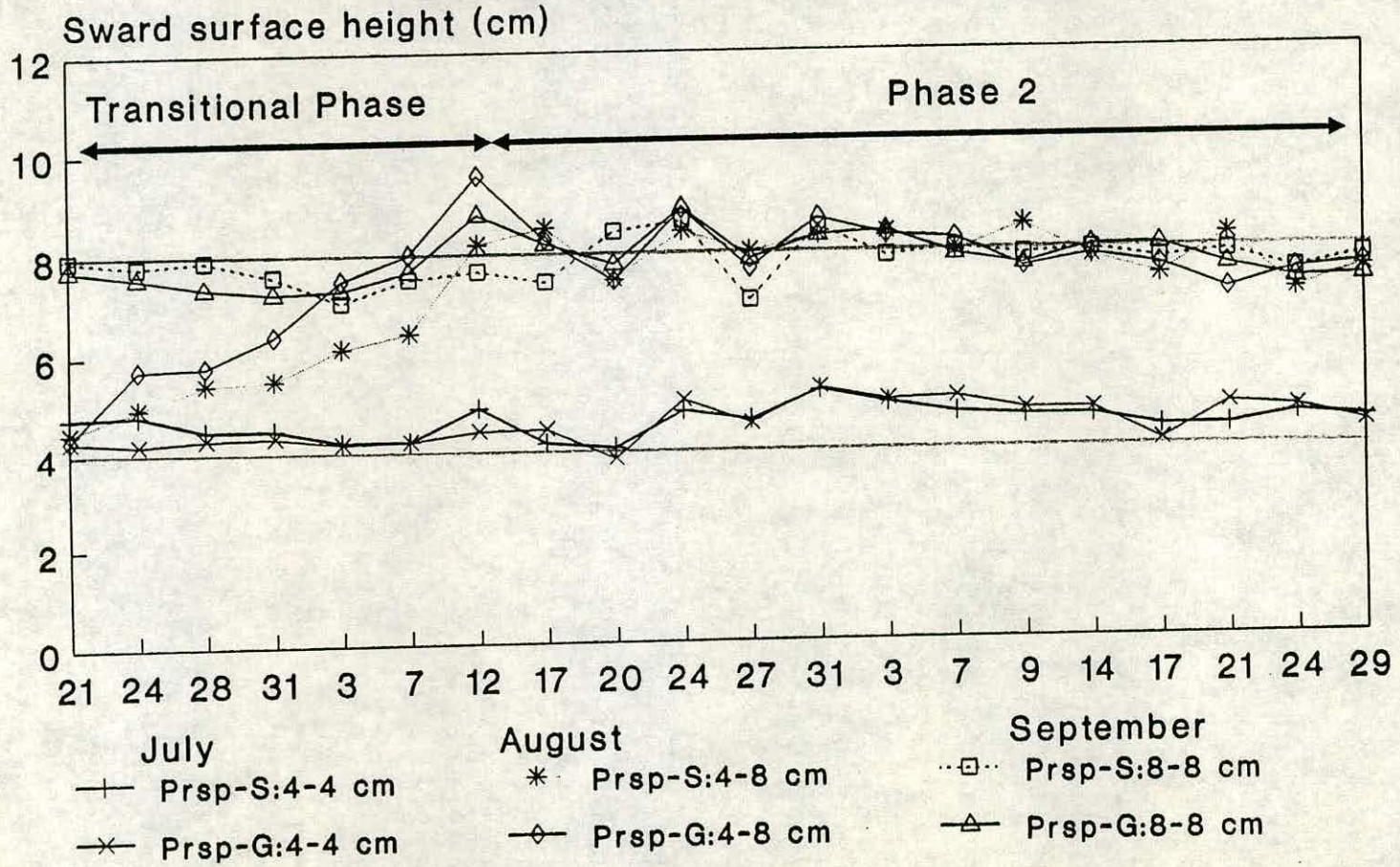
Figure 4.5 illustrates the pattern of sward heights on all treatments during the transitional phase between Phases 1 and 2 and during Phase 2. The transitional phase took place from 21 July to 12 August during which time the 4-8 cm height treatment plots grew to the target height of 8 cm. From then, Table 4.3 describes the overall mean sward heights between treatments during Phase 2.

Table 4.3. Mean sward surface heights (cm) during Phase 2 (n = 1400).

pre-species	sheep			goat			
Height (cm)	4-4	4-8	8-8	4-4	4-8	8-8	sed.
Sward height	4.6	8.0	7.9	4.6	8.0	8.0	0.24

Sward height treatments (4.6 cm, 8.0 cm and 7.9 cm for treatments 4-4, 4-8 and 8-8 cm respectively; sed 0.16) were successfully imposed. Pre-species treatments had no effect on sward surface height and there was no significant pre-species x sward height interaction.

Figure 4.5. Pattern of change of sward surface heights in Phase 2.



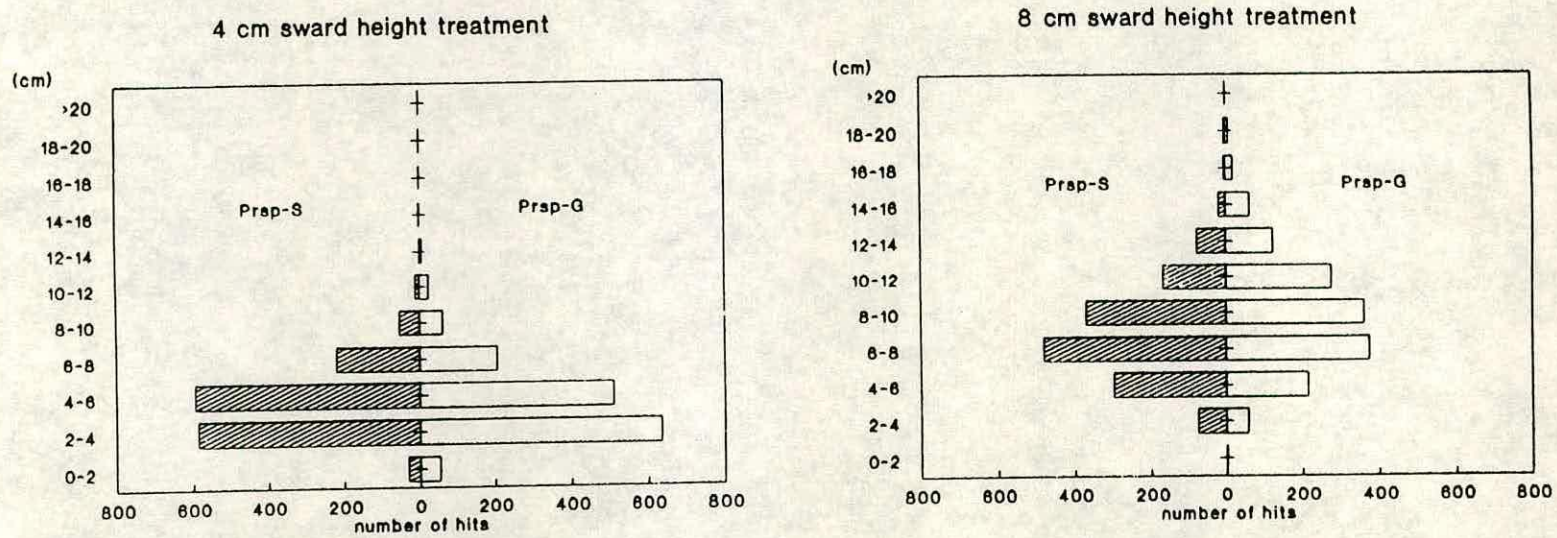
4.4.2.1. Sward height patchiness.

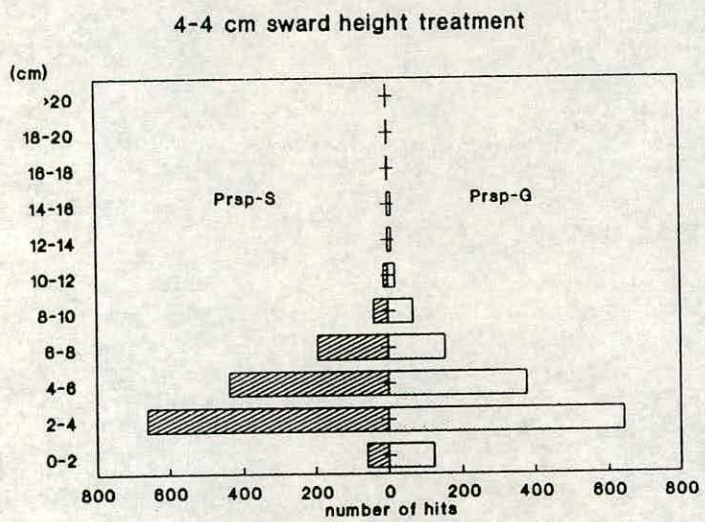
Figures 4.6 and 4.7 show histograms of the frequency distribution of sward height measurements in Phase 1 and in Phase 2 respectively. Following the same procedure used in Experiment 1 (Section 3.4.2.1), comparisons between pre-species treatments were carried out by comparing the proportion of measurements above 8 cm using Pearson's chi-square (χ^2).

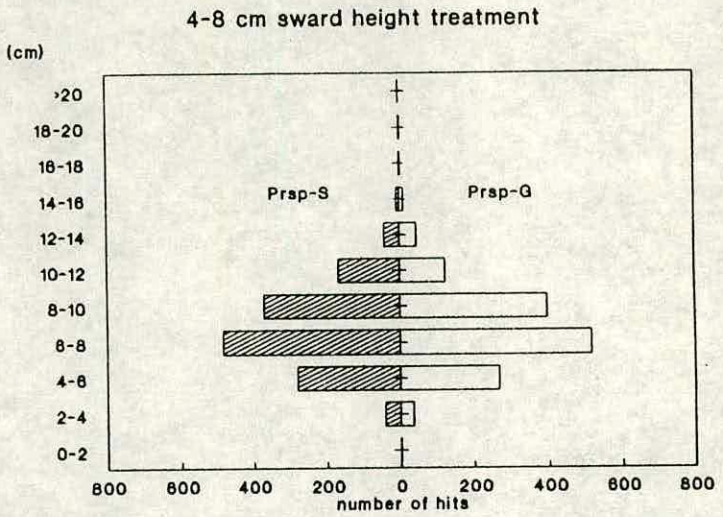
In Phase 1, a total of 3000 sward heights were recorded for each pre-species (Prsp-S or Prsp-G) treatment. On the 4 cm treatment, 6.2% versus 4.5% of measurements on Prsp-G and Prsp-S treatments respectively were recorded above 8 cm (χ^2=4.46; df=1; $p<0.05$). On the 8 cm treatment, 56.7% versus 43.0% of measurements on Prsp-G and Prsp-S treatments respectively were above 8 cm (χ^2=56.58; df=1; $p<0.001$). Taken together these results indicate a greater degree of heterogeneity in height on the goat grazed swards (Prsp-G).

In Phase 2 a total of 1400 measurements of sward heights were made for each pre-species x sward height treatment and their distribution is shown in Figure 4.7. On treatment 4-4 cm the distribution of heights between Prsp-G and Prsp-S were highly significantly different with 7.7% versus 3.7% respectively above 8 cm (χ^2=20.79; df=1; $p<0.001$). Also, on treatment 8-8 cm the differences were significant: 43.0% (Prsp-G) and 39.0% (Prsp-S) of the heights were above 8 cm (χ^2=4.80; df=1; $p<0.05$). There were no differences between pre-species treatments on treatment 4-8 cm: 41.5% versus 42.3% of measurements for Prsp-G and Prsp-S respectively were above 8 cm (χ^2=0.17; df=1; ns).

Figure 4.6. Frequency distribution of sward surface height measurements (classified in 2 cm bands) during Phase 1.







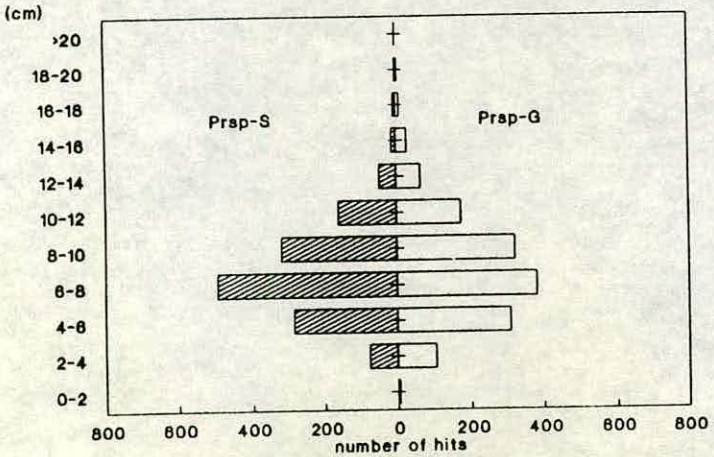


Figure 4.7. Frequency distribution of sward surface height measurements (classified in 2 cm bands) during Phase 2.

4.4.2.2. Sward herbage mass.

Figure 4.8 shows the herbage mass on each pre-species x sward height treatment throughout the experiment.

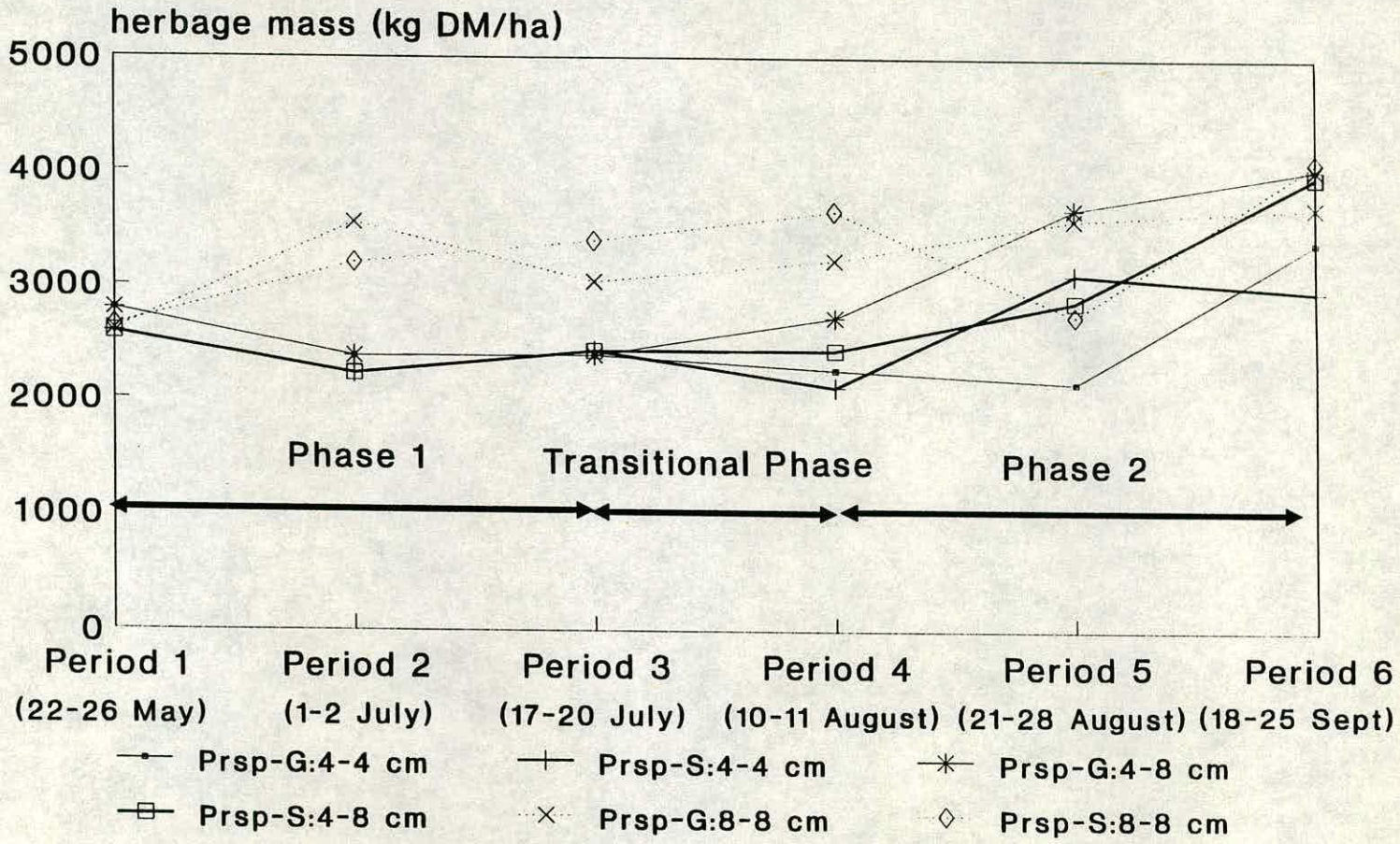
In Phase 1, paddocks grazed either by goats or by sheep showed similar overall masses (2794 versus 2748 kg DM/ha respectively; sed. 83.2; ns) but obviously differed between the height treatments (3075 versus 2467 kg DM/ha on 8 cm and 4 cm treatments respectively; sed. 83.2; $p<0.01$).

In Phase 2, pre-species treatments in Phase 1 did not result in differences in herbage mass (3206 versus 3116 kg DM/ha on Prsp-G and on Prsp-S treatments respectively; sed. 92.8; ns). There were significant differences due to sward height treatments (2675, 3295 and 3513 kg DM/ha for 4-4 cm, 4-8 cm and 8-8 cm treatments respectively; sed. 113.7; $p<0.01$). Herbage mass increased ($p<0.001$) on the 4-8 cm treatments during Phase 2.

4.4.3. Sward composition.

Following the same procedure for reporting the results as in Experiment 1, the sward composition is described in each Phase, firstly considering the data for the whole sward and then for the 'sward surface'. The number of observations used in all the tables describing the botanical composition (from Table 4.4 to Table 4.11) are two ($n = 2$).

Figure 4.8. Herbage mass over six sampling periods (Periods 1, 2, 3, 4, 5 and 6) throughout Experiment 2.



4.4.3.1. Phase 1.

4.4.3.1.1. *Sward.*

a) Phase 1

Table 4.4 shows the percentage of each of the five botanical components during Phase 1 for each sampling period while Figure 4.9 displays graphically the changes which occurred during Phase 1 in percentages of grass, clover and other species in the whole sward. No initial differences existed between treatments at the start of the experiment (Period 1). Initial mean values were 68.5% live grass, 6.8% dead grass, 21.7% live clover, 0.2% dead clover, 2.7% other species and 0.1% unidentified material.

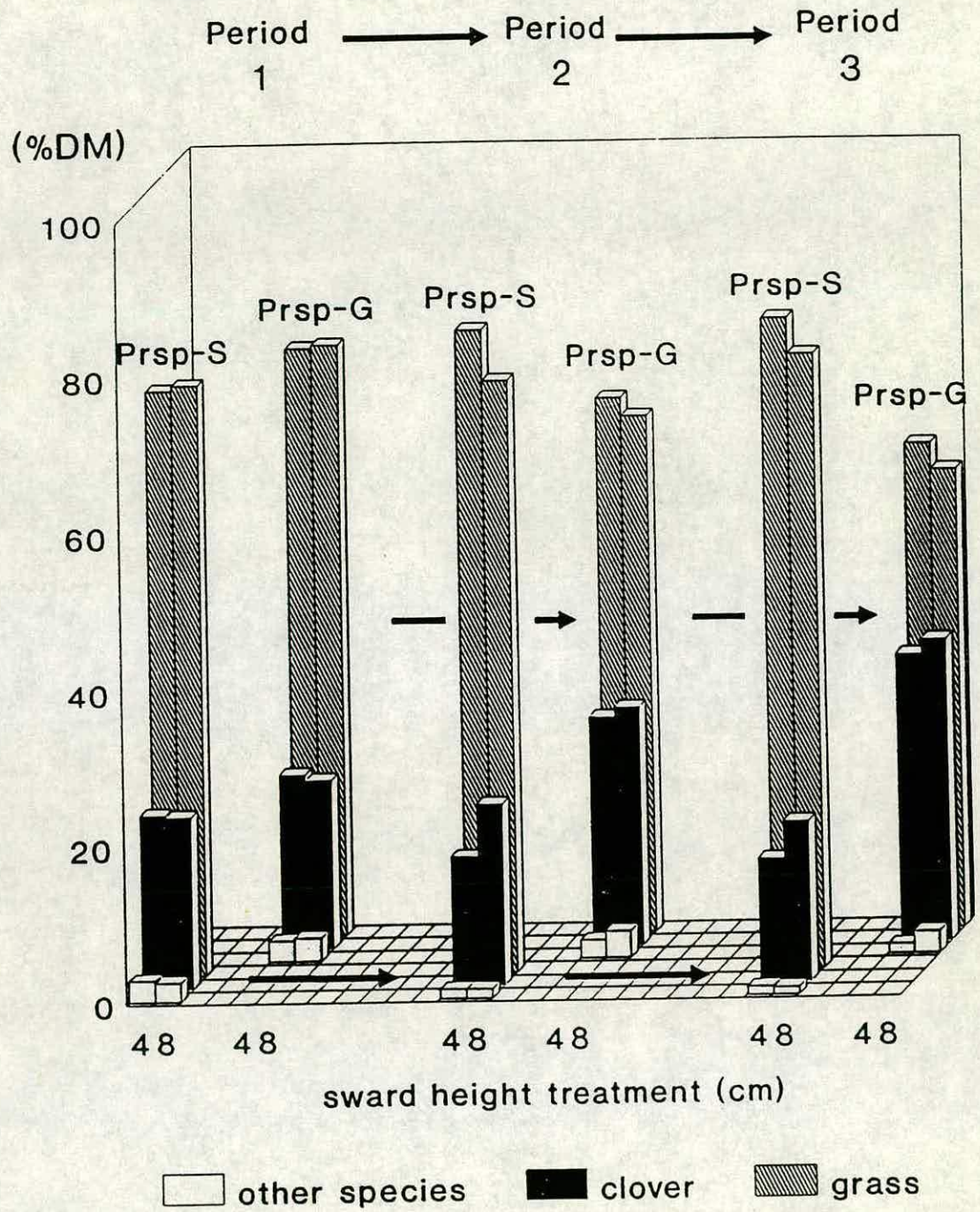
During Phase 1, the animal species which grazed the swards had an effect on the way the botanical composition of the swards developed. By the end of Phase 1 (Period 3), the Prsp-G treatment had developed a significantly higher percentage of clover compared to the Prsp-S treatment (37.7% versus 18.1%; sed. 3.94; $p<0.05$). This was also the case for live clover (which accounted for between 91% and 99% of total clover) and dead clover ($p<0.05$ and $p<0.01$ respectively in Period 3). On the Prsp-G treatment at the end of Phase 1 (Period 3), the percentages of live grass and of dead grass were lower than on the Prsp-S treatment (43.6% versus 57.5% live grass; sed. 3.08; $p<0.05$ and 16.6% versus 23.4% dead grass; sed. 2.30; $p<0.1$).

Sward height treatment did not affect the percentage of live clover or live grass. The percentage of dead grass increased during the course of Phase 1 ($p<0.001$).

Table 4.4. Botanical components (%DM) of the whole sward classified by pre-species treatment (sheep or goats) and by sward height treatment (4 cm or 8 cm) in Periods 1, 2 and 3 during Phase 1.

Animal pre-species in Phase 1 (Prsp)		Sheep		Goat			Level of significance		
Sward height treatment (Height; cm)		4	8	4	8	sed	Prsp	Height	Prsp x Height
Component	**Period**								
Live grass	1(Start)	68.5	68.6	68.7	68.2	1.00	ns	ns	ns
	2	57.6	62.7	54.5	52.1	5.90	ns	ns	ns
	3	54.3	60.6	45.7	41.5	4.36	*	ns	ns
Dead grass	1(Start)	6.4	6.9	6.4	7.3	0.53	ns	ns	ns
	2	24.5	13.0	13.7	13.9	1.18	*	**	**
	3	28.9	17.9	16.2	17.0	3.25	p=0.059	ns	ns
Live clover	1(Start)	21.9	21.7	22.1	21.3	0.88	ns	ns	ns
	2	15.9	21.8	28.1	27.5	4.57	p=0.070	ns	ns
	3	15.0	19.4	35.2	35.4	5.34	*	ns	ns
Dead clover	1(Start)	0.2	0.2	0.2	0.2	0.02	ns	ns	ns
	2	0.6	1.2	1.2	3.0	0.43	*	*	ns
	3	0.8	1.0	1.6	3.1	0.34	**	*	ns
Other species	1(Start)	2.7	2.4	2.6	3.0	0.34	ns	ns	ns
	2	1.2	1.2	2.3	3.4	0.48	*	ns	ns
	3	1.1	0.9	1.3	2.8	0.85	ns	ns	ns

Figure 4.9. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species in the whole sward of the 4 cm and 8 cm sward height treatments grazed by sheep (Prsp-S) or goats (Prsp-G) on three occassions in Phase 1 (Periods 1, 2 and 3).



This increase was greatest on the Prsp-S: 4 cm treatment such that by Period 2 it had the highest percentage of dead grass (pre-species x sward height interaction, $p<0.01$) and this trend was still evident in Period 3 at the end of Phase 1 (see Table 4.4). Finally, percentages of dead clover were higher on the 8 cm height treatment than on the 4 cm height treatment ($p<0.05$ in Periods 2 and 3 respectively).

Figures 4.10 and 4.11 describe the vertical distribution of live and dead grass and clover respectively grouped by horizon, pre-species and sward height treatments while Tables 4.5 and 4.6 show the overall amounts of the five botanical components of the sward classified by horizon, by pre-species and sward height treatment in Period 1 and in Periods 2 and 3 respectively.

During Phase 1, there were significant differences in amounts of clover and of grass in each horizon: 495 (0-2 cm), 115 (2-4 cm), 51 (4-6 cm) and 59 (>6 cm) kg clover DM/ha (sed. 13.3; $p<0.001$) in Period 2, 520 (0-2 cm), 133 (2-4 cm), 65 (4-6 cm) and 70 (>6 cm) kg clover DM/ha (sed. 13.7; $p<0.001$) in Period 3, 1474 (0-2 cm), 264 (2-4 cm), 135 (4-6 cm) and 183 (>6 cm) kg grass DM/ha (sed. 14.1; $p<0.001$) in Period 2 and 1456 (0-2 cm), 234 (2-4 cm), 116 (4-6 cm) and 175 (>6 cm) kg grass DM/ha (sed. 14.2; $p<0.001$) in Period 3. In addition the amounts of live grass, dead grass, live clover, dead clover and other species all showed significant differences between horizons in both sampling periods ($p<0.001$). In Phase 1 throughout all horizons, clover ($p<0.001$), live clover ($p<0.001$), dead clover ($p<0.001$) and dead grass amounts ($p<0.001$) increased whereas in most of the horizons (0-2 cm, 2-4 cm and 4-6 cm horizons) live grass decreased ($p<0.001$).

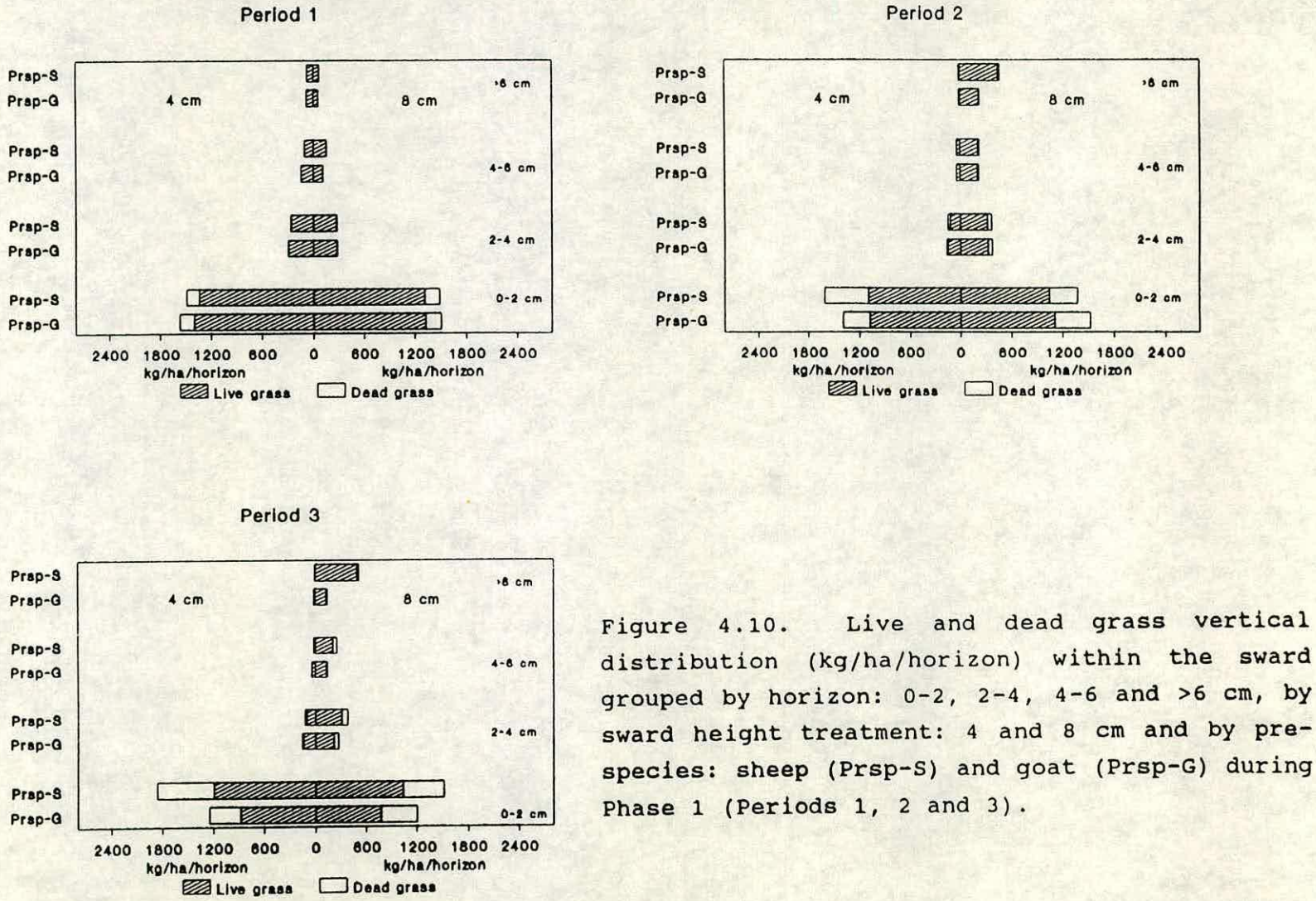


Figure 4.10. Live and dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height treatment: 4 and 8 cm and by pre-species: sheep (Prsp-S) and goat (Prsp-G) during Phase 1 (Periods 1, 2 and 3).

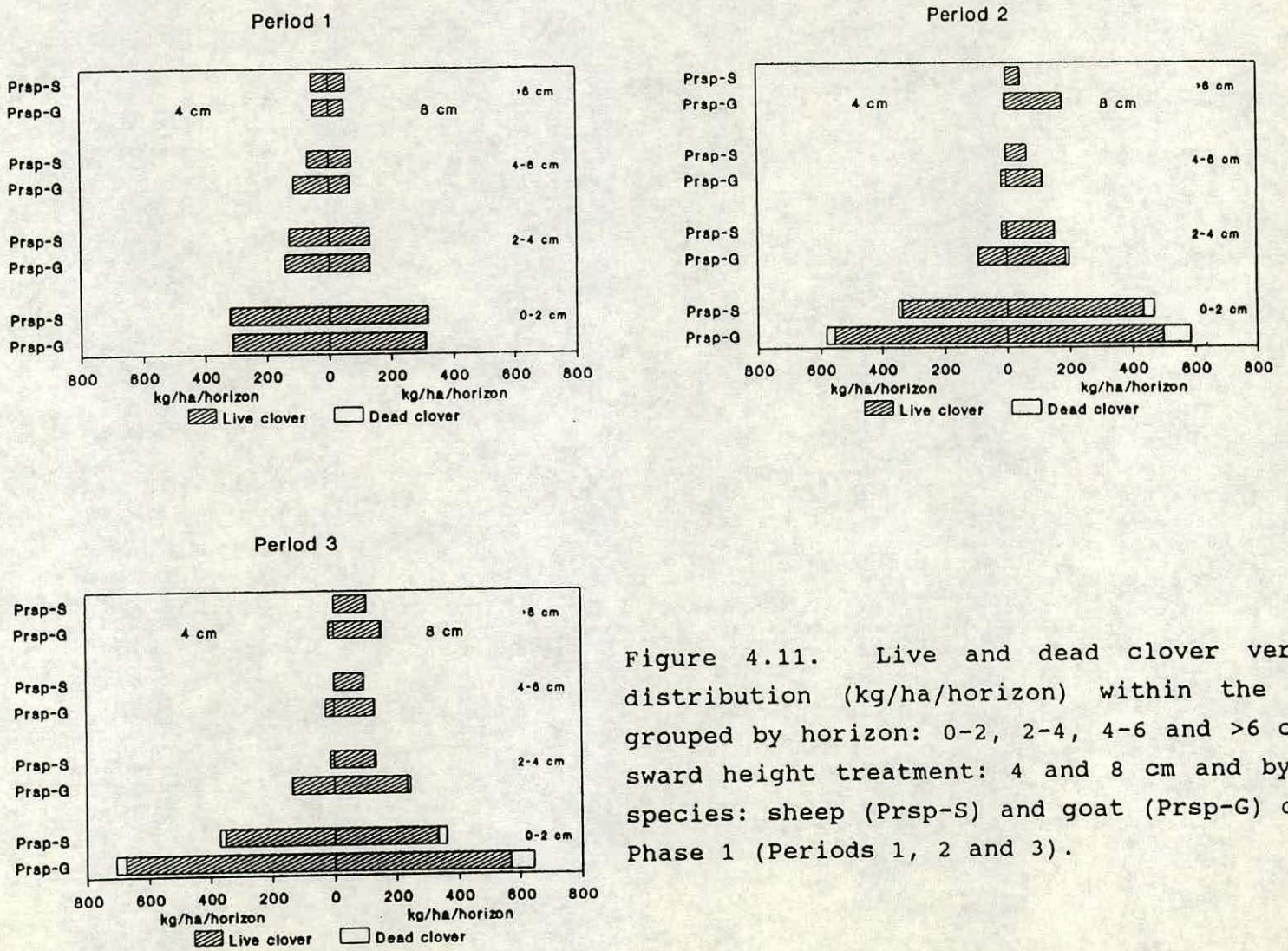


Figure 4.11. Live and dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height treatment: 4 and 8 cm and by pre-species: sheep (Prsp-S) and goat (Prsp-G) during Phase 1 (Periods 1, 2 and 3).

Table 4.5. Botanical components (kg/ha/horizon) of the whole sward grouped by pre-species treatment (sheep and goats), by sward height treatment (4 cm or 8 cm) and by horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) in Period 1 at the start of Phase 1.

Animal pre-species in Phase 1 (Prsp)		Sheep		Goat			Level of significance
Sward height treatment (cm) (Height)		4	8	4	8	sed[a]	
Component	**Horizon** (cm) (H)						
Live grass	0-2	1334	1315	1400	1324		
	2-4	259	272	289	279	39.0	
	4-6	104	154	145	112		H ***
	>6	74	71	84	60		
Dead grass	0-2	156	170	174	179		
	2-4	8	7	7	7	7.3	H ***
	4-6	1	1	1	3		
	>6	1	0	1	1		
Live clover	0-2	316	314	308	308		
	2-4	128	131	142	130	14.1	H ***
	4-6	69	74	113	67		
	>6	54	55	52	49		
Dead clover	0-2	5	4	5	4		
	2-4	0	0	0	0	0.4	H ***
	4-6	0	0	0	0		
	>6	0	0	0	0		
Other species	0-2	60	53	70	59		
	2-4	3	5	3	7	4.1	H ***,
	4-6	6	4	1	10		Height x H *
	>6	1	1	0	2		

([a]- sed. of means of the interaction Prsp x Height x H).

Table 4.6. Botanical components (kg/ha/horizon) of the whole sward grouped by pre-species treatment (sheep or goats), by sward height treatment (4 or 8 cm) and by horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) in Periods 2 and 3 during Phase 1. (*- sed. of means of interaction Prsp x Height x H).

Pre-species (Prsp)			Sheep		Goat			
Sward height treatment (Height; cm)			4	8	4	8	sed*	Level of significance
Component	Period	Horizon (H; cm)						
Live grass	2	0-2	1100	1038	1084	1107	54.9	Height *, H ***, Prsp x H *, Height x H ***, Prsp x Height x H *
		2-4	121	320	152	326		
		4-6	41	207	47	201		
		>6	15	449	15	221		
	3	0-2	1189	1043	880	781	47.8	Prsp *, Height *, H ***, Prsp x Height (p=0.055), Prsp x H ***, Height x H ***, Prsp x Height x H **
		2-4	99	317	141	222		
		4-6	20	211	41	127		
		>6	11	492	20	130		
Dead grass	2	0-2	509	335	310	415	20.9	Prsp x Height *, H ***, Prsp x H *, Height x H (p=0.057), Prsp x Height x H ***
		2-4	30	43	15	49		
		4-6	7	18	2	17		
		>6	0	19	1	10		
	3	0-2	671	471	365	425	27.0	Prsp *, H ***, Prsp x H ***, Height x H **, Prsp x Height x H ***
		2-4	21	69	15	54		
		4-6	3	42	3	18		
		>6	2	27	1	17		
Live clover	2	0-2	336	434	555	498	43.4	Prsp *, Height *, H ***, Prsp x H *, Height x H (p=0.069), Prsp x Height x H *
		2-4	17	149	92	187		
		4-6	3	67	17	112		
		>6	1	47	6	178		
	3	0-2	351	334	675	570	80.6	Prsp (p=0.079), H ***, Prsp x H **, Height x H *
		2-4	14	129	133	236		
		4-6	2	93	28	128		
		>6	0	105	17	150		
Dead clover	2	0-2	13	33	26	87	5.8	Prsp *, Height **, H ***, Prsp x Height *, Prsp x H ***, Height x H ***, Prsp x Height x H *
		2-4	0	4	2	11		
		4-6	0	1	0	7		
		>6	0	1	0	4		
	3	0-2	18	26	32	74	5.0	Prsp *, Height *, H ***, Prsp x H ***, Height x H ***, Prsp x Height x H **
		2-4	0	5	3	10		
		4-6	0	3	1	4		
		>6	0	1	2	6		
Other Species	2	0-2	26	29	42	55	8.9	Prsp **, Height *, Prsp x Height *, H ***
		2-4	2	6	6	21		
		4-6	0	2	4	10		
		>6	0	1	3	35		
	3	0-2	24	24	22	47	10.5	H ***
		2-4	3	4	4	16		
		4-6	0	2	2	9		
		>6	0	1	2	18		

At the end of Phase 1 (Period 3), within horizon there was more clover on the Prsp-G treatment than on the Prsp-S treatment: 675 versus 364 (0-2 cm) kg clover DM/ha, 191 versus 74 (2-4 cm) kg clover DM/ha, 80 versus 49 (4-6 cm) kg clover DM/ha and 87 versus 53 (>6 cm) kg clover DM/ha (sed. 40.4; $p<0.1$). Conversely, sheep-grazed paddocks (Prsp-S) had more grass than goat-grazed paddocks (Prsp-G): 1687 versus 1225 (0-2 cm) kg grass DM/ha, 253 versus 216 (2-4 cm) kg grass DM/ha, 138 versus 94 (4-6 cm) kg grass DM/ha and 266 versus 84 (>6 cm) kg grass DM/ha (sed. 41.6; $p<0.001$). Also by the end of Phase 1, clover masses were greater on the 8 cm than on the 4 cm height treatment in the 2-4 cm horizon (190 versus 75 kg clover DM/ha), in the 4-6 cm horizon (114 versus 15 kg clover DM/ha) and in the >6 cm horizon (131 versus 9 kg clover DM/ha) but not in the 0-2 cm horizon (502 versus 538 kg clover DM/ha; sed. 40.4; ns). Grass amounts showed a significant difference between the 8 cm and 4 cm height treatments with more grass in the taller horizons as would be expected: 331 versus 138 (2-4 cm horizon) kg grass DM/ha, 199 versus 34 (4-6 cm horizon) kg grass DM/ha and 333 versus 17 (>6 cm) kg grass DM/ha but not in the 0-2 cm horizon as there were 1360 versus 1552 kg grass DM/ha (overall sed. 41.6; $p<0.01$).

There was a highly significant interaction between pre-species x horizon x sampling period on the amounts of clover. On the Prsp-S treatment the clover decreased between the start of the experiment (Period 1) and Periods 2 and 3 on the 2-4 cm (129.3 versus 85.2 and 73.9 kg DM/ha), 4-6 cm (71.1 versus 35.2 and 49.1 kg DM/ha) and >6 cm horizons (54.4 versus 24.0 and 52.7 kg clover DM/ha) but not on the 0-2 cm horizon (319.4 versus 408.1 and 364.5 kg clover DM/ha; Periods 1, 2 and 3 respectively) while on the Prsp-G treatment, the total clover increased on the 0-2 cm (312.3 versus 582.8 and 675.3 kg clover DM/ha), on the 2-4 cm (136.1 versus 145.4 and 191.7 kg clover DM/ha) and on

the >6 cm horizon (51.0 versus 93.7 and 87.6 kg clover DM/ha) but not on the 4-6 cm (90.2 versus 67.6 and 80.2 kg clover DM/ha; Periods 1, 2 and 3 respectively)(overall sed. 38.60; $p<0.001$). This interaction was also significant for the amounts of live grass ($p<0.001$), dead grass ($p<0.001$), live clover ($p<0.01$) and dead clover ($p<0.001$).

4.4.3.1.2. *Sward surface.*

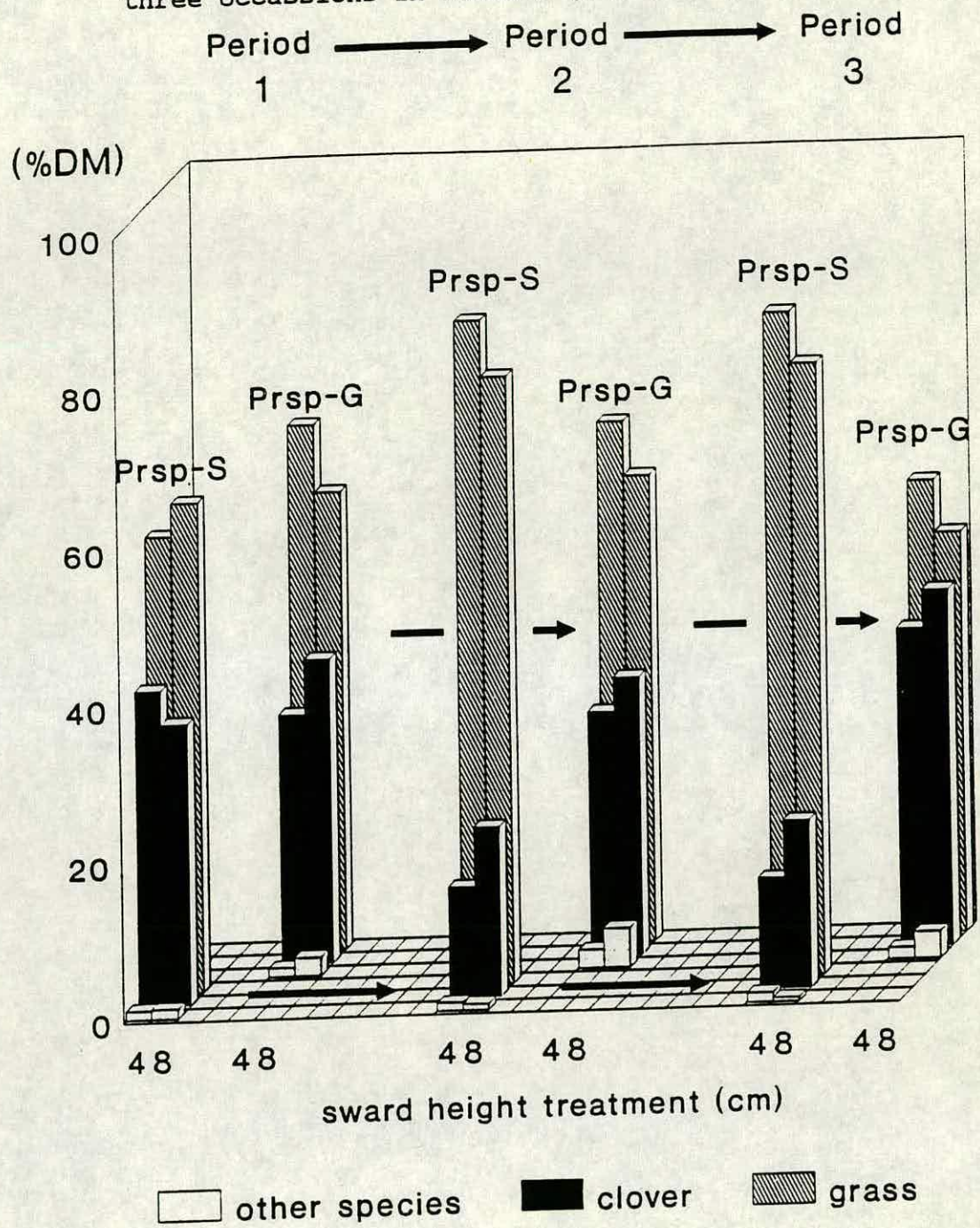
Table 4.7 describes the percentages of the five major botanical components on the 'sward surface' in each sampling period during Phase 1. Figure 4.12 displays the percentages of grass, clover and other species on the sward surface of each pre-species x sward height treatment combination through each sampling period during Phase 1.

While percentage of clover in the Prsp-S treatment decreased through Phase 1: 38.1% (Period 1), 17.9% (Period 2) and 17.8% (Period 3), it increased on the Prsp-G treatment: 35.3% (Period 1), 33.3% (Period 2) and 43.0% (Period 3; sed. 3.82; $p<0.001$). Also, there were similar significant changes in percentage of live clover ($p<0.001$) while percentages of live grass showed the opposite changes ($p<0.05$). Whereas the Prsp-G treatment showed an increase in percentage dead clover from Period 1 to Period 2 (0.1% versus 1.3%; sed. 0.31; $p<0.001$), percentages of dead grass increased significantly during Phase 1 ($p<0.05$) both on the Prsp-S and on Prsp-G treatments and to a greater extent on the Prsp-S treatment.

Table 4.7. Botanical components (% DM) of the sward surface classified by pre-species treatment (sheep or goats) and by sward height treatment (4 cm or 8 cm) in Periods 1, 2 and 3 during Phase 1.

Animal pre-species in Phase 1 (Prsp)		Sheep		Goat			Level of significance		
Sward height treatment (Height; cm)		4	8	4	8	sed	Prsp	Height	Prsp x Height
Component	**Period**								
Live grass	1(Start)	57.7	61.7	64.2	57.3	2.81	ns	ns	ns
	2	62.3	70.0	55.4	55.3	7.92	ns	ns	ns
	3	59.0	69.0	47.6	42.0	5.34	*	ns	ns
Dead grass	1(Start)	0.6	0.9	2.8	1.3	0.98	ns	ns	ns
	2	22.4	7.4	11.0	6.2	1.25	**	**	*
	3	25.6	9.0	10.3	9.2	4.64	ns	ns	ns
Live clover	1(Start)	40.2	35.9	31.7	38.6	4.40	ns	ns	ns
	2	13.7	21.1	30.1	33.7	6.76	p=0.056	ns	ns
	3	13.6	20.9	39.4	43.6	4.91	**	ns	ns
Dead clover	1(Start)	0.0	0.0	0.1	0.2	0.03	**	*	*
	2	0.4	0.6	1.0	1.7	0.45	ns	ns	ns
	3	0.6	0.5	1.2	1.8	0.62	ns	ns	ns
Other species	1(Start)	1.1	1.2	1.2	2.4	1.14	ns	ns	ns
	2	1.0	0.8	2.4	5.0	0.59	**	ns	*
	3	1.2	0.5	1.5	3.4	0.87	ns	ns	ns

Figure 4.12. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species on the 'sward surface' of the 4 cm and 8 cm sward height treatments grazed by sheep (Prsp-S) or goats (Prsp-G) on three occassions in Phase 1 (Periods 1, 2 and 3).



Sward height treatments had no significant effects on live grass or live clover although percentages of dead grass increased dramatically between Periods 1 to 2 both on the 4 cm and on the 8 cm height treatments, particularly on the 4 cm height treatment (1.7% versus 16.7%; sed. 1.83; $p<0.001$) such that the pre-species x sward height treatment interaction was significant ($p<0.05$) in Period 2.

4.4.3.2. Phase 2.

4.4.3.2.1. *Sward.*

The percentage of the five botanical components through all sampling periods (Periods 4, 5 and 6) during Phase 2, are given in Table 4.8.

Initially in Period 4, the Prsp-G treatment (plots previously grazed by goats) had higher percentages of clover (37.5% versus 23.8%; sed. 1.19; $p<0.001$), live clover (35.1% versus 23.0%; sed. 1.18; $p<0.001$), dead clover (2.3% versus 0.8%; sed. 0.17; $p<0.001$) and other species (2.4% versus 0.9%; sed. 0.43; $p<0.001$) but lower percentages of grass (60.1% versus 75.2%; sed. 1.31; $p<0.001$), live grass (44.1% versus 56.5%; sed. 0.93; $p<0.001$) and of dead grass (16.0 versus 18.7%; sed. 0.67; $p<0.01$) than the Prsp-S treatment (plots previously grazed by sheep).

Table 4.8. Botanical components (% DM) of the whole sward classified by pre-species treatment (sheep or goats) and by sward height treatment (4-4 cm, 4-8 cm and 8-8 cm) in Periods 4, 5 and 6 during Phase 2.

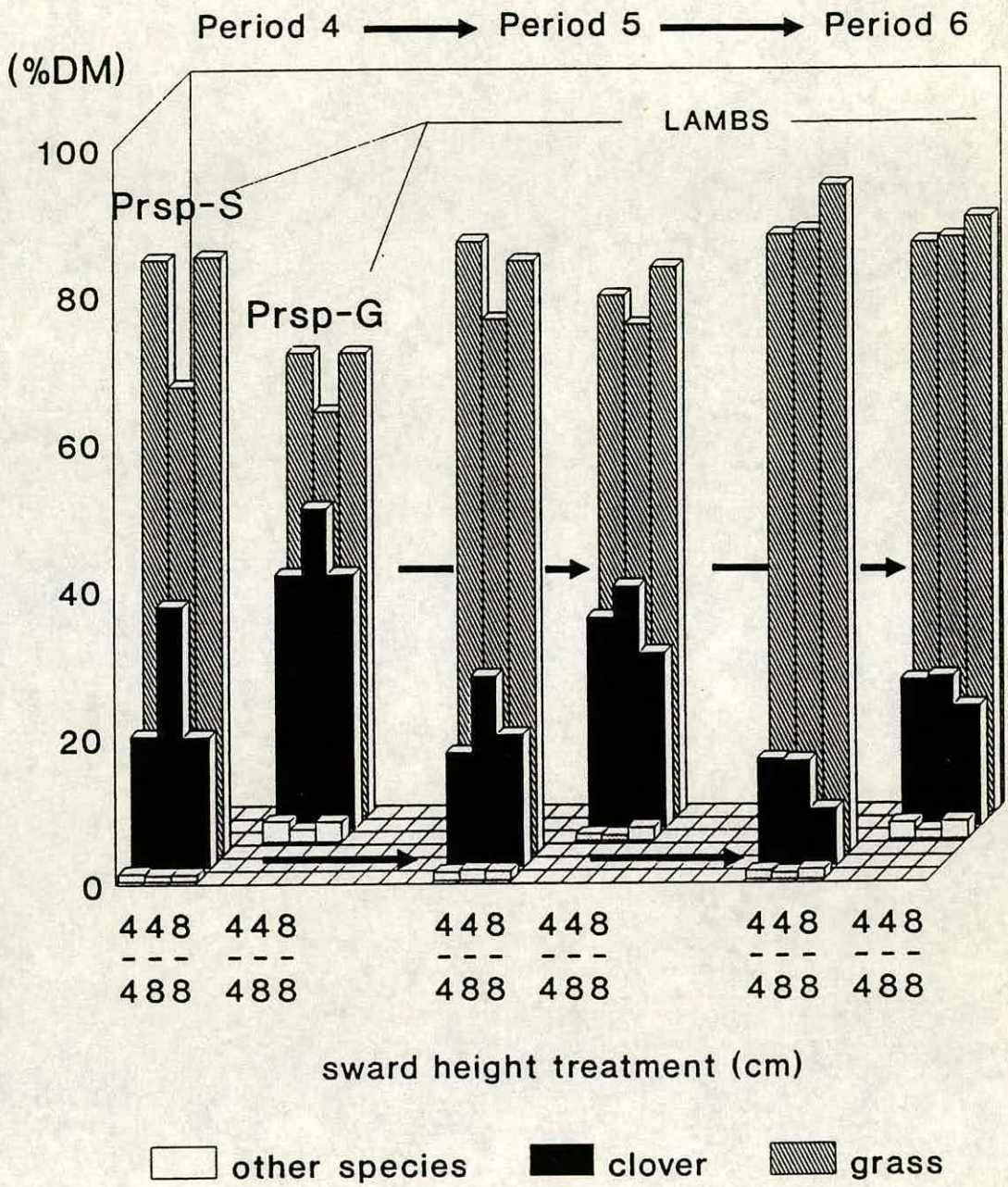
Animal pre-species in Phase 1 (Prsp)		Sheep			Goat				Level of significance		
Sward height treatment (Height; cm)		4-4	4-8	8-8	4-4	4-8	8-8	sed	Prsp	Height	Prsp x Height
Component	**Period**										
Live grass	4(Start)	57.4	53.6	58.5	45.4	42.9	44.1	1.61	***	p=0.066	ns
	5	58.2	62.5	56.8	51.9	52.2	52.9	3.52	*	ns	ns
	6	57.3	57.4	57.0	44.7	55.8	53.6	2.80	*	p=0.079	p=0.077
Dead grass	4(Start)	23.4	9.9	22.7	17.4	11.9	18.7	1.18	*	***	*
	5	25.0	10.1	23.8	18.6	14.3	21.5	4.15	ns	*	ns
	6	26.8	27.3	33.9	33.0	22.6	27.5	3.01	ns	ns	p=0.060
Live clover	4(Start)	17.3	34.9	16.9	32.7	41.0	31.6	2.05	***	***	*
	5	15.2	24.6	17.3	27.3	30.1	21.7	4.23	*	ns	ns
	6	13.7	13.5	7.1	19.1	18.3	15.2	2.31	**	*	ns
Dead clover	4(Start)	0.7	0.7	1.0	1.7	2.4	2.9	0.30	***	*	ns
	5	0.5	1.4	0.8	1.3	2.6	2.1	0.39	**	*	ns
	6	1.0	0.9	0.8	0.9	2.2	1.3	0.32	*	ns	p=0.055
Other species	4(Start)	1.1	0.8	0.9	2.8	1.7	2.7	0.74	*	ns	ns
	5	1.1	1.4	1.3	0.9	0.7	1.8	0.85	ns	ns	ns
	6	1.2	0.9	1.3	2.3	1.2	2.5	0.91	ns	ns	ns

Also between sward height treatments, the 4-8 cm sward height treatment in contrast to the 4-4 cm and the 8-8 cm sward height treatments respectively had a higher percentage of clover (39.5% versus 26.2% and 26.2%; sed. 1.46; $p<0.001$) and live clover (38.0% versus 25.0% and 24.2%; sed. 1.45; $p<0.001$) but lower percentages of grass (59.2% versus 71.8% and 72.0%; sed. 1.61; $p<0.001$), live grass (48.3% versus 51.4% and 51.3%; sed. 1.13; $p<0.1$) and dead grass (10.9% versus 20.4% and 20.7%; sed. 0.83; $p<0.001$). Percentages of dead clover also varied between sward height treatments with the 8-8 cm height treatment having the highest value (2.0% versus 1.2% and 1.5% for the 8-8 cm, 4-4 and the 4-8 cm height treatments respectively; sed. 0.21; $p<0.05$). The interaction between pre-species x sward height treatment was significant for the percentage of clover ($p<0.05$), live clover ($p<0.05$), grass ($p<0.05$) and dead grass ($p<0.05$) with the Prsp-G:4-8 cm treatment combination having the highest percentage of clover and the Prsp-S:4-4 cm and Prsp-S:8-8 cm treatments having the lowest values.

From Period 4, percentages of clover decreased significantly during Phase 2: 30.7% (Period 4), 24.2% (Period 5) and 15.7% (Period 6; sed. 1.01; $p<0.001$). Also there were decreases in the percentages of live clover (29.1%-Period 4, 22.7%-Period 5 and 14.5%-Period 6; sed. 0.98; $p<0.001$) and of dead clover (1.6%-Period 4, 1.5% - Period 5 and 1.2%-Period 6; sed. 0.15; $p<0.1$). Conversely, percentages of dead grass increased from Period 5 to Period 6 (from 18.9% to 28.5%; sed. 1.12; $p<0.001$) while percentage of live grass increased from Period 4 to Period 5 (from 50.3% to 55.8%; sed. 1.29; $p<0.01$).

Figure 4.13 shows the changes in percentages of grass, clover and other species grouped by pre-species and sward height treatments during Phase 2.

Figure 4.13. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species in the whole sward of the 4-4 cm, 4-8 cm and 8-8 cm sward height treatments grazed by weaned lambs in Phase 2 (Periods 4, 5 and 6) after have been grazed by sheep (Prsp-S) or goats (Prsp-G) in Phase 1.



Decreases of percentages of clover through Phase 2 were greater on the Prsp-G treatment: 37.5% (Period 4), 28.4% (Period 5) and 19.0% (Period 6) than on the Prsp-S treatment: 23.8% (Period 4), 19.9% (Period 5) and 12.4% (Period 6; sed. 2.40; $p<0.05$), although at the end of Phase 2 the Prsp-G treatment still had a higher percentage of clover than the Prsp-S treatment ($p<0.01$). Percentage live clover showed similar decreases ($p<0.05$) whereas percentage of dead clover mainly decreased between Periods 5 and 6 on Prsp-G treatment (from 2.0% to 1.5%; sed. 0.19; $p<0.05$). Increases in percentage of live grass occurred on both pre-species treatments (with larger increases on the Prsp-G treatment) between Periods 4 and 5 ($p=0.053$) although by Period 6, the Prsp-S treatment still had a higher percentage value than the Prsp-G treatment (57.2% versus 51.4%; sed. 1.61; $p<0.01$).

Sward height treatments also affected the percentage of clover and changes in percentage of clover in Phase 2. Clover percentage values were 26.2% (Period 4), 22.1% (Period 5) and 17.4% (Period 6) on the 4-4 cm height treatment, 39.5% (Period 4), 29.4% (Period 5) and 17.5% (Period 6) on the 4-8 cm height treatment, and 26.2% (Period 4), 20.9% (Period 5) and 12.2% (Period 6) on the 8-8 cm height treatment (sed. 2.21; $p<0.01$). Similar changes occurred in the percentages of live clover ($p<0.01$) while the largest decrease in percentage of dead clover occurred on the 8-8 cm height treatment during Phase 2 (2.0%-Period 4, 1.5%-Period 5 and 1.0%-Period 6; sed. 0.23; $p<0.05$).

Furthermore, there was an interaction ($p<0.05$) between pre-species and sward height treatments in change in percentage of dead grass by Period 6; the 8-8 cm height treatment had a higher percentage of dead grass in those plots previously grazed by sheep (Prsp-S; 33.9%) than in those previously grazed by goats (27.5%; sed. 3.17; $p<0.01$)

but conversely on the 4-4 cm height treatment, a higher percentage occurred when the plots had been previously grazed by goats (Prsp-G; 33.0%) than previously grazed by sheep (Prsp-S; 26.8%; ns).

Table 4.9 contains the masses of the botanical components at the start of Phase 2 (Period 4) and Table 4.10 shows the botanical components in Periods 5 and 6. Figures 4.14 and 4.15 show the vertical distribution of the masses of live and dead grass and clover respectively through Phase 2 (Periods 4, 5 and 6). Overall, in Phase 2 as the height above ground level of the horizon increased, the mass of clover (456, 126, 69 and 61 kg DM/ha; sed 9.5; $p<0.001$) and of grass (1759, 314, 155 and 175 kg DM/ha; sed. 33.7; $p<0.001$) decreased. But from Period 4 to Period 6, across all the horizons there was a decrease in clover masses: -103.6, -57.9, -48.9 and -52.0 kg DM/ha in the 0-2 cm, 2-4 cm, 4-6 cm and >6 cm horizons respectively (sed. 16.53; $p<0.05$). The same occurred with live clover mass ($p<0.05$) while dead clover mass did not change significantly. The reverse was true for live grass ($p<0.001$) and dead grass masses ($p<0.001$) in all horizons.

In comparing the pre-species treatments within horizon during Phase 2, there were greater amounts of clover in all horizons on the Prsp-G treatment compared to the Prsp-S treatment in Period 4 (sed. 26.38; $p<0.001$): 617.0 versus 412.4 (0-2 cm) kg clover DM/ha, 194.7 versus 112.3 (2-4 cm) kg clover DM/ha, 117.5 versus 65.1 (4-6 cm) kg clover DM/ha and 102.3 versus 46.2 (>6 cm) kg clover DM/ha; in Period 5 (sed. 24.90; $p<0.05$): 500.3 versus 384.2 (0-2 cm) kg clover DM/ha, 164.5 versus 94.3 (2-4 cm) kg clover DM/ha, 86.7 versus 57.9 (4-6 cm) kg clover DM/ha and 134.7 versus 38.6 (>6 cm) kg clover DM/ha; and also in Period 6 (sed. 22.22; $p<0.001$): 489.6 versus 332.7 (0-2 cm) kg clover DM/ha, 118.2 versus 73.0 (2-4 cm) kg clover DM/ha,

55.5 versus 29.2 (4-6 cm) kg clover DM/ha and 32.7 versus 11.7 (>6 cm) kg clover DM/ha. Masses of live clover (overall $p<0.001$) and of dead clover (overall $p<0.001$) followed similar patterns. Masses of grass mainly differed in the basal horizon (0-2 cm; $p<0.001$) where the Prsp-S treatment had higher masses that the Prsp-G treatment in Period 4 (1471 versus 1222 kg grass DM/ha; sed. 31.1), in Period 5 (2348 versus 1269 kg grass DM/ha; sed. 93.9) and in Period 6 (2378 versus 2187 kg grass DM/ha; sed. 98.8).

Throughout Phase 2, the 4-8 cm sward height treatment had more clover than the 4-4 cm and 8-8 cm height treatments ($p<0.001$) in Period 4 (sed. 32.31, $p<0.05$): 536.1 versus 515.9 and 492.1 (0-2 cm) kg clover DM/ha, 233.7 versus 52.8 and 174.0 (2-4 cm) kg clover DM/ha, 145.4 versus 11.4 and 117.0 (4-6 cm) kg clover DM/ha, and 117.5 versus 0.8 and 104.3 (>6 cm) kg clover DM/ha; in Period 5 (sed. 30.49; $p<0.01$): 454.1 versus 466.2 and 406.4 (0-2 cm) kg clover DM/ha, 203.6 versus 60.5 and 124.2 (2-4 cm) kg clover DM/ha, 148.7 versus 12.3 and 55.8 (4-6 cm) kg clover DM/ha and 167.5 versus 4.5 and 88.0 (>6 cm) kg clover DM/ha; and in Period 6 (sed. 27.22; $p<0.001$): 423.9 versus 515.4 and 294.1 (0-2 cm) kg clover DM/ha, 162.0 versus 30.4 and 94.4 (2-4 cm) kg clover DM/ha, 78.1 versus 7.9 and 41.1 (4-6 cm) kg clover DM/ha and 25.7 versus 3.6 and 37.3 (>6 cm) kg clover DM/ha. As expected the 8-8 cm sward height treatment had more grass than the 4-8 cm and the 4-4 cm sward height treatments in all horizons (overall $p<0.001$). From Periods 4 to 6, the 4-8 cm and 8-8 cm sward height treatments had significant decreases in the masses of live clover ($p<0.05$) in all horizons but particularly in the top horizon (>6 cm) while plots with the 4-4 cm sward height treatment only showed a non-significant decrease in the 2-4 cm horizon.

Table 4.9. Botanical components (kg/ha/horizon) of the whole sward grouped by pre-species treatment (sheep and goats), by sward height treatment (4-4 cm, 4-8 cm and 8-8 cm) and by horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) in Period 4 at the start of Phase 2.

Pre-species (Prsp)		Sheep			Goat				Level of significance
Sward height treatment (Height; cm)		4-4	4-8	8-8	4-4	4-8	8-8	sed*	
Component	**Horizon** (cm) (H)								
Live grass	0-2	1102	850	1155	901	655	888		Prsp ***, Height ***, H ***,
	2-4	89	235	327	102	194	245	45.5	Prsp x Height **,
	4-6	20	120	210	24	133	153		Prsp x H ***, Height x H ***,
	>6	4	103	455	5	185	142		Prsp x Height x H *
Dead grass	0-2	478	216	610	380	298	545		Prsp *, Height ***, H ***,
	2-4	14	16	96	11	16	34	16.4	Prsp x Height **,
	4-6	3	5	51	1	5	20		Height x H ***,
	>6	1	3	75	1	2	8		Prsp x Height x H ***
Live clover	0-2	342	496	349	646	516	553		Prsp **, Height **, H ***,
	2-4	21	200	108	81	255	223	43.3	Prsp x H **,
	4-6	3	98	91	15	189	126		Height x H **,
	>6	0	60	73	1	171	120		Prsp x Height x H **
Dead clover	0-2	13	12	26	30	48	57		Prsp ***,
	2-4	0	1	6	3	11	11	4.6	Height **,
	4-6	0	0	4	5	4	13		H ***,
	>6	1	2	2	0	2	13		Prsp x H ***
Other Species	0-2	22	17	21	53	28	50		Prsp *,
	2-4	1	3	5	8	9	19	6.8	H ***,
	4-6	1	1	2	1	6	11		Prsp x H **,
	>6	0	0	4	0	7	8		Height x H (p=0.067)

(*- sed. of means of the interaction Prsp x Height x H).

Table 4.10. Botanical components (kg/ha/horizon) of the whole sward grouped by pre-species treatment (sheep or goats), by sward height treatment (4-4 cm, 4-8 cm and 8-8 cm) and by horizon (0-2 cm, 2-4 cm, 4-6 cm and >6 cm) in Periods 5 and 6 during Phase 2.

Pre-species (Prsp)			Sheep			Goat				
Sward height treatment (Height; cm)			4-4	4-8	8-8	4-4	4-8	8-8	sed*	Level of significance
Component	Period	Horizon (H; cm)								
		0-2	1559	1094	1136	880	1068	1061		H ***, Prsp x Height *,
	5	2-4	183	357	232	147	344	335	79.0	Prsp x H ***,
		4-6	48	200	102	59	210	199		Height x H ***,
		>6	14	150	93	47	310	310		Prsp x Height x H **
Live grass										
		0-2	1416	1489	1483	1282	1255	1189		
	6	2-4	195	446	427	161	510	399	99.3	Height *,
		4-6	70	207	208	43	246	220		H ***,
		>6	25	137	210	27	252	183		Prsp x H *
		0-2	788	272	498	389	477	658		
	5	2-4	12	13	51	9	29	78	94.8	H ***,
		4-6	1	4	37	1	12	28		Prsp x Height x H *
		>6	0	1	70	0	15	14		
Dead grass										
		0-2	777	1007	964	1112	799	923		
	6	2-4	15	51	123	19	71	60	107.9	Prsp x Height (p=0.076),
		4-6	4	21	66	2	34	21		H ***
		>6	2	10	245	3	36	15		
		0-2	418	312	354	474	503	406		Prsp **, Height *,
	5	2-4	40	153	83	78	229	143	40.8	H ***,
		4-6	5	140	27	19	148	75		Prsp x H (p=0.060),
		>6	0	103	12	9	221	150		Height x H ***
Live clover										
		0-2	360	349	206	614	423	329		Prsp **, Height *, H ***,
	6	2-4	32	118	59	24	180	119	35.9	Prsp x H ***,
		4-6	11	52	20	5	91	56		Height x H ***,
		>6	3	22	5	3	19	61		Prsp x Height x H ***
		0-2	15	34	20	26	59	33		Prsp **,
	5	2-4	0	6	1	3	20	21	7.8	Height *,
		4-6	0	1	1	0	8	9		H ***,
		>6	0	0	0	0	10	14		Height x H (p=0.078)
Dead clover										
		0-2	31	28	24	26	47	30		Prsp **,
	6	2-4	1	7	3	4	19	9	4.6	Height **,
		4-6	0	1	3	0	12	3		Prsp x Height *,
		>6	0	2	3	1	8	6		H ***
		0-2	36	28	29	17	12	48		
	5	2-4	1	7	5	2	4	7	10.5	H ***
		4-6	0	4	1	1	2	7		
		>6	0	1	1	0	8	3		
Other Species										
		0-2	33	29	31	75	29	60		
	6	2-4	3	5	22	3	9	9	13.9	H ***,
		4-6	0	1	4	2	4	8		Prsp x H (p=0.087)
		>6	0	0	0	0	0	14		

(*- sed of means of the interaction Prsp x Height x H).

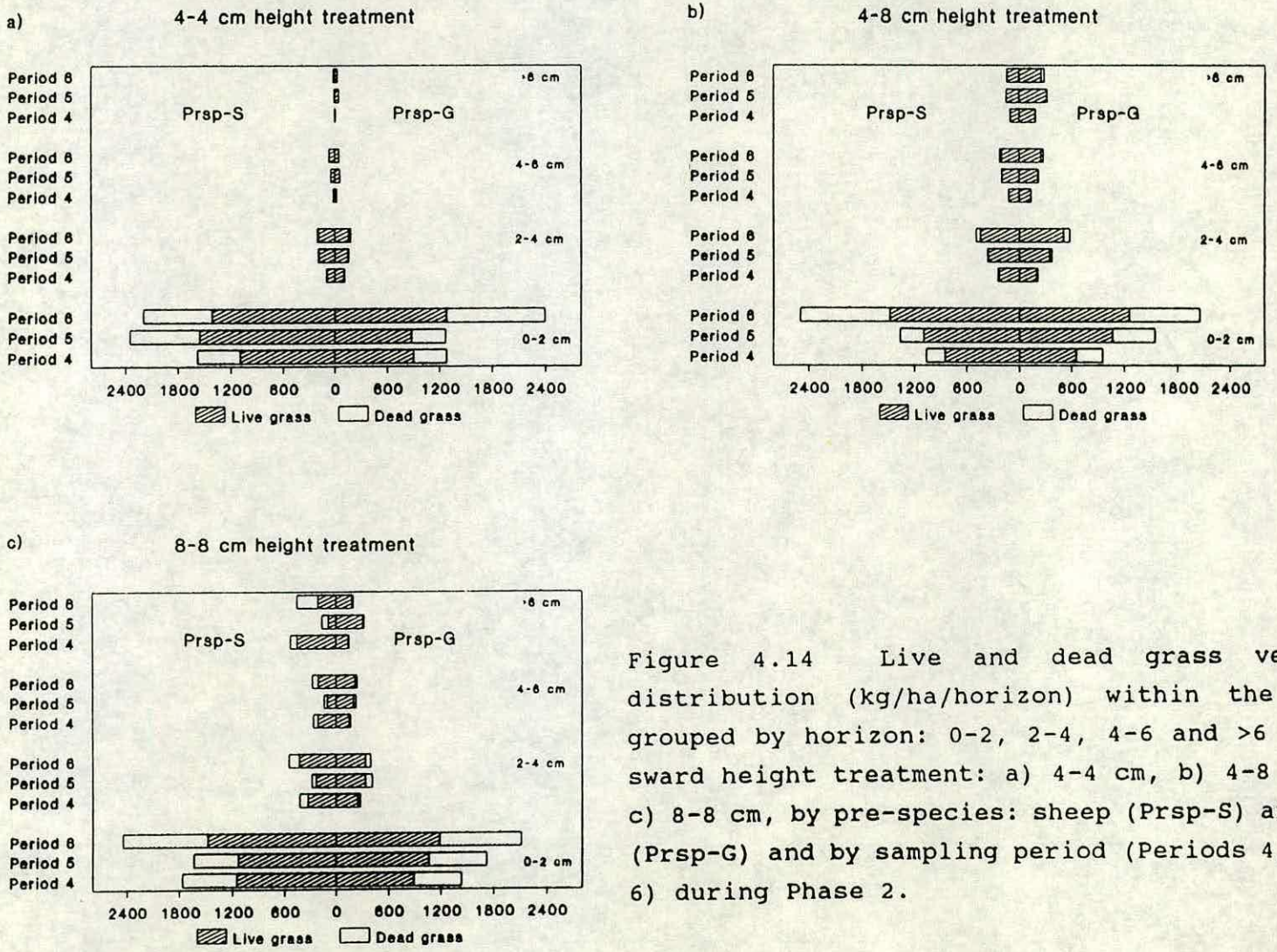


Figure 4.14 Live and dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height treatment: a) 4-4 cm, b) 4-8 cm and c) 8-8 cm, by pre-species: sheep (Prsp-S) and goat (Prsp-G) and by sampling period (Periods 4, 5 and 6) during Phase 2.

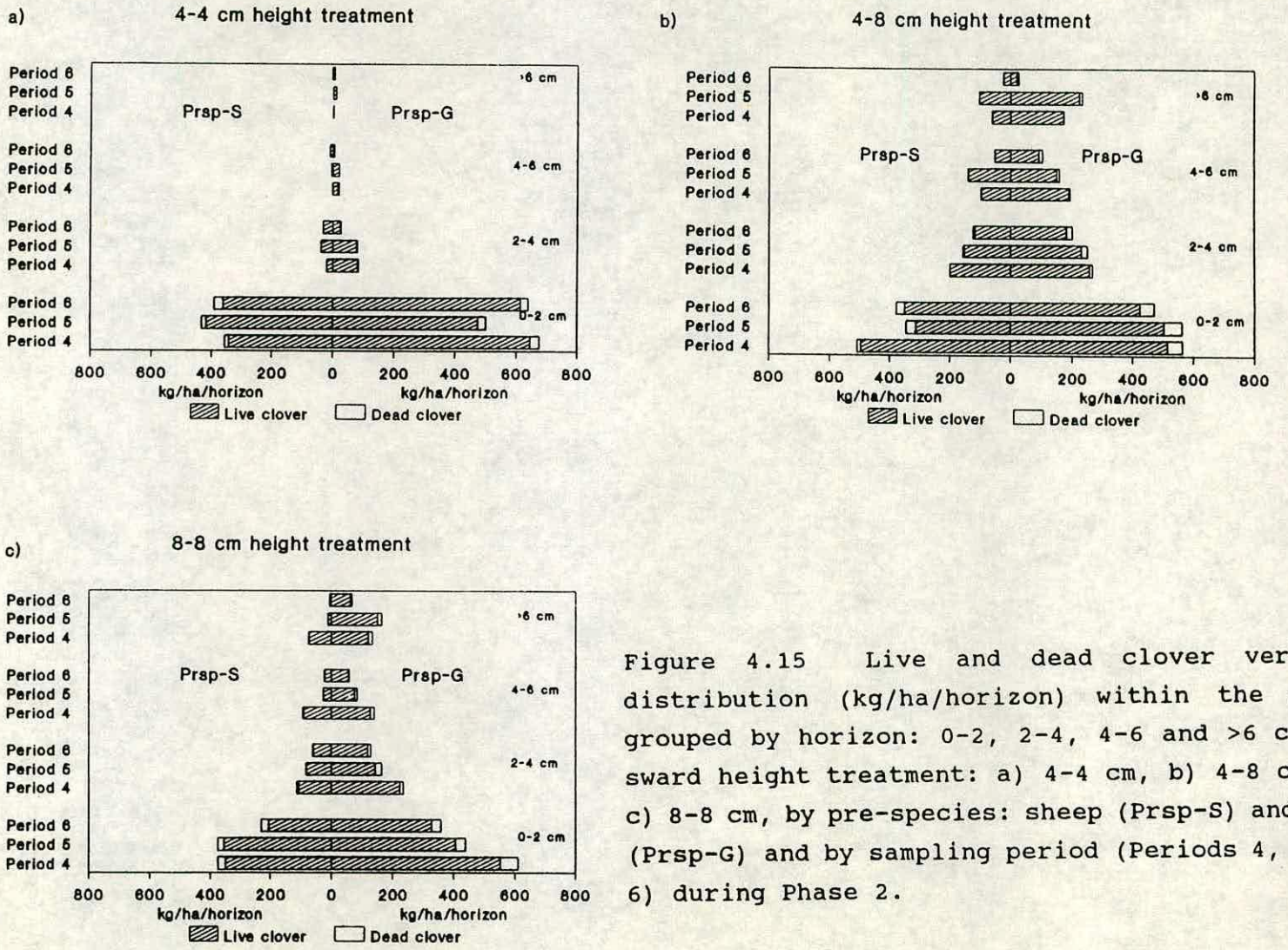


Figure 4.15 Live and dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height treatment: a) 4-4 cm, b) 4-8 cm and c) 8-8 cm, by pre-species: sheep (Prsp-S) and goat (Prsp-G) and by sampling period (Periods 4, 5 and 6) during Phase 2.

Overall, the treatment combination Prsp-G:4-8 cm had more clover mass than any treatment combination in the 2-4 cm, 4-6 cm and >6 cm horizons (interaction pre-species x sward height category x horizon was $p<0.01$) across all sampling periods (Periods 4, 5 and 6) during Phase 2 (see Figure 4.15).

4.4.3.2.2. *Sward surface.*

Table 4.11 shows the percentages of the botanical components in the sward surface in each sampling period during Phase 2. Initially in Period 4, in the sward surface, the Prsp-G treatment had higher percentages of clover (43.8% versus 25.6%; sed. 1.32; $p<0.001$), live clover (41.7% versus 25.0%; sed. 1.36; $p<0.001$), dead clover (2.1% versus 0.6%; sed. 0.23; $p<0.01$) and other species (2.8% versus 0.6%; sed. 0.77; $p<0.05$) but lower percentages of live grass (47.1% versus 61.6%; sed. 1.43; $p<0.001$) and dead grass (6.2% versus 12.1%; sed. 1.40; $p<0.01$) than the Prsp-S treatment. The 4-8 cm height treatment had higher percentages of clover (47.1% versus 26.8% and 30.4%; sed. 1.62; $p<0.001$) and live clover (46.2% versus 25.7% and 28.2%; sed. 1.66; $p<0.001$) but lower percentages of live grass (50.0% versus 55.0% and 58.2%; sed. 1.75; $p<0.05$) and dead grass (2.0% versus 15.9% and 9.6%; sed. 1.40; $p<0.001$) than the 4-4 cm and 8-8 cm treatments. The 8-8 cm sward height treatment recorded the highest percentage dead clover (2.1% versus 1.1% and 0.8% on the 8-8 cm, 4-4 cm and 4-8 cm sward height treatments respectively; sed. 0.28; $p<0.05$).

Table 4.11. Botanical components (% DM) of the sward surface classified by pre-species treatment (sheep or goats) and by sward height treatment (4-4 cm, 4-8 cm or 8-8 cm) in Periods 4, 5 and 6 during Phase 2.

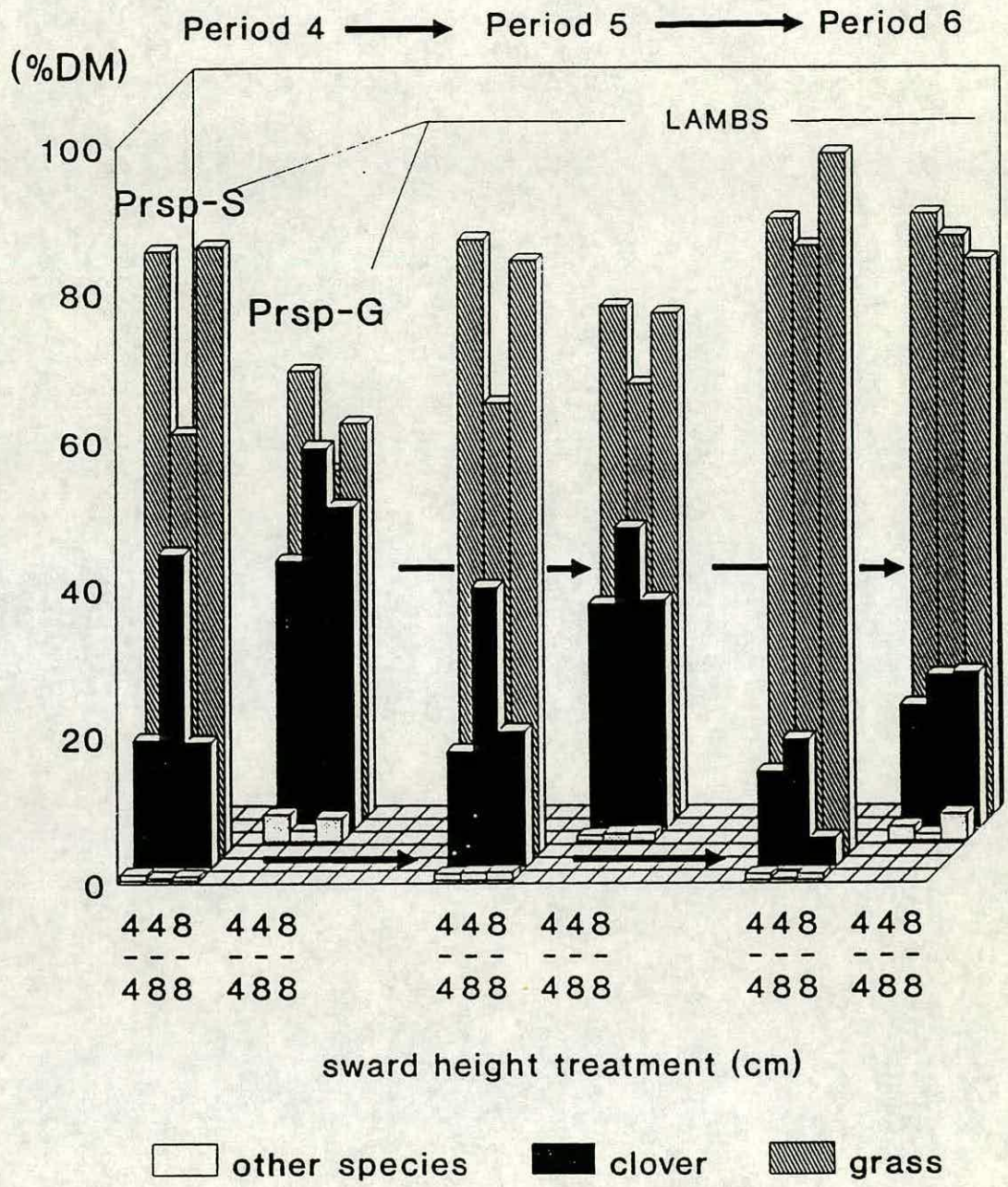
Pre-species (Prsp)		Sheep			Goat				Level of significance		
Sward height treatment (Height; cm)		4-4	4-8	8-8	4-4	4-8	8-8	sed	Prsp	Height	Prsp x Height
Component	Period										
Live grass	4(Start)	61.6	54.5	68.8	48.4	45.4	47.6	2.47	•••	•	•
	5	63.3	59.4	60.3	57.6	55.1	60.2	5.38	ns	ns	ns
	6	73.1	75.5	52.5	59.8	69.3	68.2	4.06	ns	•	••
Dead grass	4(Start)	20.1	2.6	13.6	11.7	1.4	5.6	2.42	••	•••	ns
	5	20.0	1.6	20.0	11.3	3.0	7.7	3.66	•	••	ns
	6	12.9	6.9	42.6	21.6	9.1	7.1	3.48	•	••	•••
Live clover	4(Start)	16.8	41.9	16.4	34.5	50.6	40.0	2.35	•••	•••	•
	5	15.4	37.4	18.1	29.1	38.6	27.9	6.08	p=0.066	•	ns
	6	12.5	16.5	3.2	15.4	17.5	19.7	3.12	•	ns	•
Dead clover	4(Start)	0.5	0.5	0.7	1.7	1.0	3.6	0.40	•••	•	•
	5	0.4	0.5	0.4	1.2	2.1	3.0	0.63	••	ns	ns
	6	0.6	0.9	0.9	1.2	3.1	1.4	0.89	p=0.081	ns	ns
Other species	4(Start)	0.9	0.4	0.6	3.7	1.5	3.2	1.33	•	ns	ns
	5	0.9	1.0	1.1	0.8	1.1	1.2	0.88	ns	ns	ns
	6	0.8	0.2	0.8	1.9	0.9	3.6	1.10	p=0.062	ns	ns

Also in Period 4, the Prsp-G and Prsp-S treatments had higher percentages of clover ($p<0.01$) and of live clover ($p<0.05$) on the 4-8 cm height treatment than on the 4-4 cm and 8-8 cm height treatments. Furthermore, the Prsp-G:8-8 cm treatment had the highest percentage of dead clover ($p<0.05$) and the treatment combinations Prsp-S:4-4 cm and Prsp-S:8-8 cm reported the highest percentages of live grass ($p<0.05$).

Figure 4.16 shows the changes throughout Phase 2 in the percentages of grass, clover and other species grouped by pre-species and sward height treatments. During Phase 2, percentages of clover decreased (34.7%, 29.0% and 15.5% in Periods 4, 5 and 6 respectively; sed. 1.51; $p<0.001$) as did the percentages of live clover (33.4%, 27.8% and 14.1% in Periods 4, 5 and 6 respectively; sed. 1.55; $p<0.001$) whereas percentages of live grass (54.4%, 59.3% and 59.6% in Periods 4, 5 and 6 respectively; sed. 1.81; $p<0.001$) and percentages of dead grass (9.2%, 10.6% and 16.7% in Periods 4, 5 and 6 respectively; sed. 1.44; $p<0.001$) increased.

Between periods, percentages of clover decreased on both the Prsp-G treatment (43.8%, 34.0% and 19.5% in Periods 4, 5 and 6 respectively) and on the Prsp-S treatment (25.6%, 24.1% and 11.5% in Periods 4, 5 and 6 respectively; sed. 2.31; $p<0.001$). Changes in percentages of live clover followed a similar pattern ($p<0.05$). Consequently, the Prsp-G treatment had higher percentages of clover than the Prsp-S treatment in Period 5 (34.0% versus 24.1%; sed. 3.26; $p<0.05$) and in Period 6 (31.9% versus 23.6%; sed. 3.51; $p<0.1$).

Figure 4.16. Dry matter percentage values of grass (live + dead), clover (live + dead) and other species on the 'sward surface' of the 4-4 cm, 4-8 cm and 8-8 cm sward height treatments grazed by weaned lambs in Phase 2 (Periods 4, 5 and 6) after have been grazed by sheep (Prsp-S) or goats (Prsp-G) in Phase 1.



During Phase 2, percentage of grass increased on the Prsp-G treatment while on the Prsp-S treatment it only increased from Period 5 to Period 6 (overall $p<0.01$): 65.0% versus 74.9% in Period 5 (sed. 3.32; $p<0.05$) and 78.4% versus 87.9% in Period 6 (sed. 2.54; $p<0.05$) on the Prsp-G and Prsp-S treatments respectively. In both Periods the Prsp-G treatment also had higher percentages of live clover ($p<0.1$ and $p<0.05$ in Periods 5 and 6 respectively), dead clover ($p<0.01$ and $p<0.1$ in Periods 5 and 6 respectively) and other species (ns and $p<0.1$ in Periods 5 and 6 respectively) but lower percentages of dead grass ($p<0.05$ and $p<0.05$ in Periods 5 and 6).

Also in Phase 2, percentage of clover decreased on the 4-4 cm (26.8%, 23.1% and 14.9%), on the 4-8 cm (47.1%, 39.3% and 19.0%) and on the 8-8 cm sward height treatments (30.4%, 24.7% and 12.6%) in Periods 4, 5 and 6 respectively (sed. 2.82; $p<0.05$). Changes on proportions of live clover followed a similar pattern ($p<0.01$). The 4-8 cm height treatment had higher percentages of live clover ($p<0.05$ in Period 5) and lower percentages of dead grass ($p<0.01$ and $p<0.01$ in Periods 5 and 6) while percentages of live grass increased throughout Phase 2 on the three sward height treatments ($p<0.01$).

4.4.4. Animal measurements.

4.4.4.1. Animal performance and output.

4.4.4.1.1. *Phase 1.*

Figure 4.17 shows the fortnightly mean live weights of the 'core' goats, ewes and lambs during Phase 1.

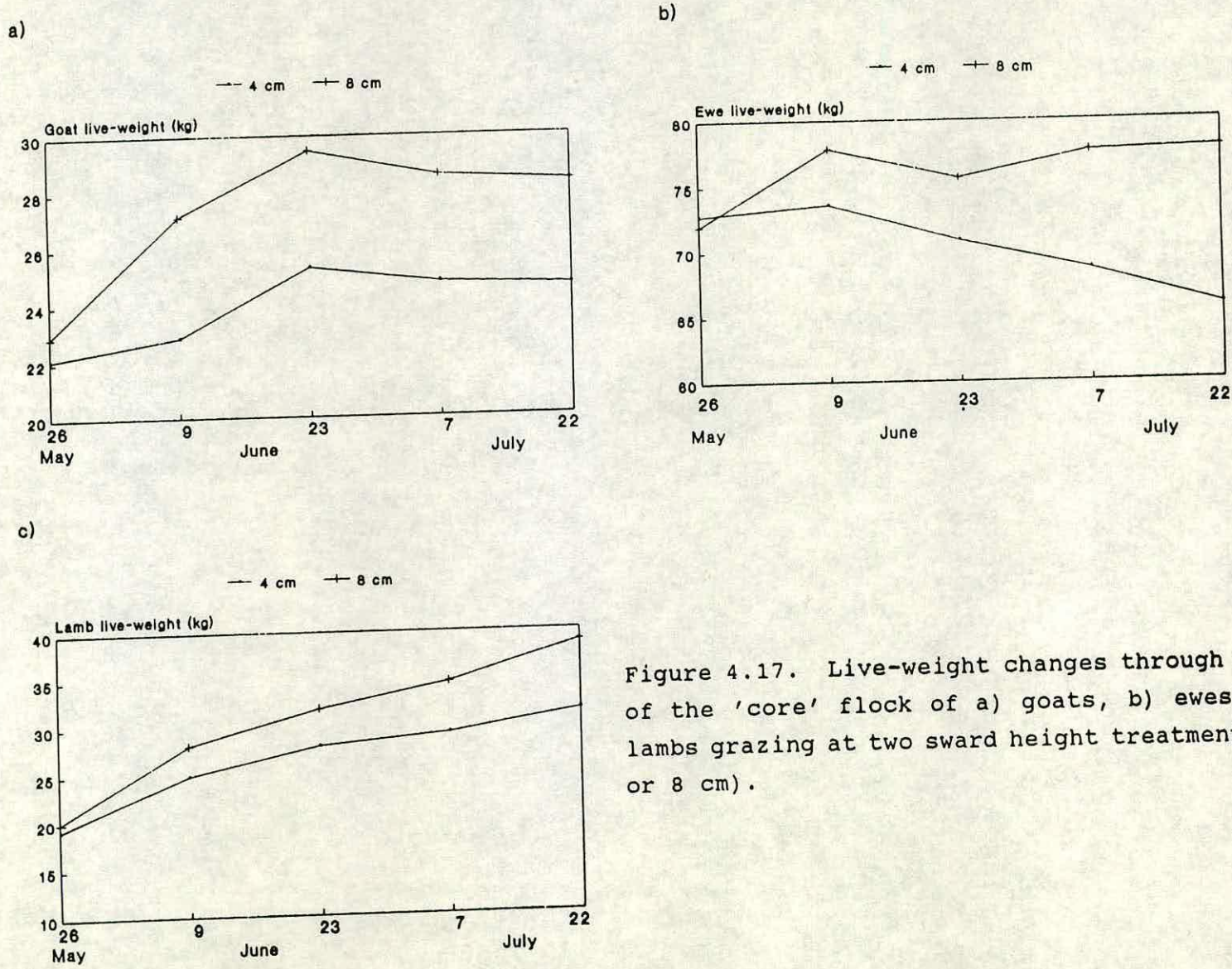


Figure 4.17. Live-weight changes through Phase 1 of the 'core' flock of a) goats, b) ewes and c) lambs grazing at two sward height treatments (4 cm or 8 cm).

- Goat performance.

Goat live weight gains were 2.4 kg/goat on the 4 cm sward versus 4.9 kg/goat on the 8 cm sward (ns) over the 57 days of Phase 1 (see Table 4.12). Goats gained live weight during the first 28 days and then lost a small amount of live weight for the remainder of Phase 1 (see Figure 4.17a).

Table 4.12. Live weight gain and body condition change in 'core' goats in Phase 1.

Height (cm)	4	8	sed	Level of significance
number of observations	83	45	-	-
Live weight gain (g/day)	42.3	85.6	17.78	ns
Body condition score increase	0.27	0.32	0.065	ns

When the total number of goats used was considered ('core' flock plus 'buffer' goats), the average stocking density was similar between sward heights treatments (149 versus 138 goats/ha on 4 cm and 8 cm treatments respectively, sed. 6.4; ns). The number of goat grazing days was higher on the 4 cm height treatment than on the 8 cm height treatment ($p<0.05$; Table 4.13). Total live weight gain was higher on the 8 cm paddocks than the 4 cm paddocks (see Table 4.13), although the difference was not significant.

Mean body condition score of 'core' goats was initially 2.3 and 2.2 on the 8 cm and 4 cm sward height treatments respectively (sed. 0.05; ns). Goats on the 8 cm height treatment increased condition score more quickly than those on the 4 cm treatment until day 28 when they had condition scores of 2.7 versus 2.3 (sed. 0.01; $p<0.05$). During the second part of Phase 1, goats on the 8 cm treatment lost body condition, making the differences between treatments smaller at the end of Phase 1 (2.6 versus 2.4 on the 8 cm and on 4 cm swards respectively; sed. 0.10; ns).

Table 4.13. Goat output during Phase 1 (n = 2).

Height (cm)	4	8	sed.	Level of significance
Goat grazing days per hectare	8493	7866	270.0	ns
Total live weight gain (kg/ha)	359	673	171.4	ns

- Sheep performance.

Ewe live weight increased by 5.8 kg/ewe on the 8 cm sward while it decreased by 7.0 kg/ewe on the 4 cm sward over the 57 days of Phase 1 (Table 4.14; Figure 4.17b).

Ewe body condition score changed little on the 4 cm treatment, while those on the 8 cm treatment gained +0.19

condition score units, although the difference between treatments was not significant.

Mean growth rates of the twin lambs were different ($p<0.05$) between sward height treatments (Table 4.14). They grew more rapidly on the 8 cm treatment (327 g/day) than on 4 cm treatment (215 g/day; sed. 4.2)(see Figure 4.17c). Consequently at the end of Phase 1, their mean live weights were 38.6 and 31.5 kg mean live weight on the 8 cm and 4 cm sward height treatments respectively (sed. 0.08; $p<0.01$).

Table 4.14. Sward height effects on the performance of the 'core' flock of ewes and lambs used during 57 grazing days on Phase 1.

Height (cm)	4	8	sed	Level of significance
number of observations	22	8	-	-
Ewe live weight change (g/day)[+]	-122	+101	11.7	*
Ewe condition score increase	0.02	0.19	0.081	ns
number of observations	44	16	-	-
Lamb live weight gain (g/day)	215	327	4.17	*

[+] Corrected for weight of wool clipped.

Average stocking density of lactating ewes (38 versus 26 ewes/ha on the 4 cm and 8 cm treatments respectively; sed. 3.3; $p<0.05$) and of their lambs (76 versus 52 lambs/ha on 4 cm and 8 cm treatments respectively; sed. 4.0; $p<0.05$) were higher on 4 cm paddocks than on 8 cm paddocks throughout Phase 1. Total ewe and lamb grazing days were calculated for each sward height treatment (Table 4.15) and were greater for 4 cm paddocks ($p<0.05$). Total live weight gains (ewes + lambs) were 1117 versus 667 kg/ha on 8 cm and 4 cm treatments respectively (sed. 6.0; $p<0.01$).

Table 4.15. Sward height effects on ewe and lamb output per hectare during Phase 1 (n = 2)

Height (cm)	4	8	sed	Level of significance
Ewe grazing days per hectare	2166	1482	23.0	*
Lamb grazing days per hectare	4332	2964	70.5	*
Ewe live weight change (kg/ha)	-264	+150	20.8	*
Lamb live weight gain (kg/ha)	931	968	14.8	ns

- Goat versus sheep.

Overall, sheep output was higher than goat output (892 versus 516 kg/ha; sed. 74.3; $p<0.05$). Although sheep output was greater than goat output on the 8 cm height treatment (1117 versus 673 kg/ha; $p<0.01$), on the 4 cm treatment the outputs were not so different (667 versus 359 kg/ha for sheep and goat output respectively; sed. 105.0; ns).

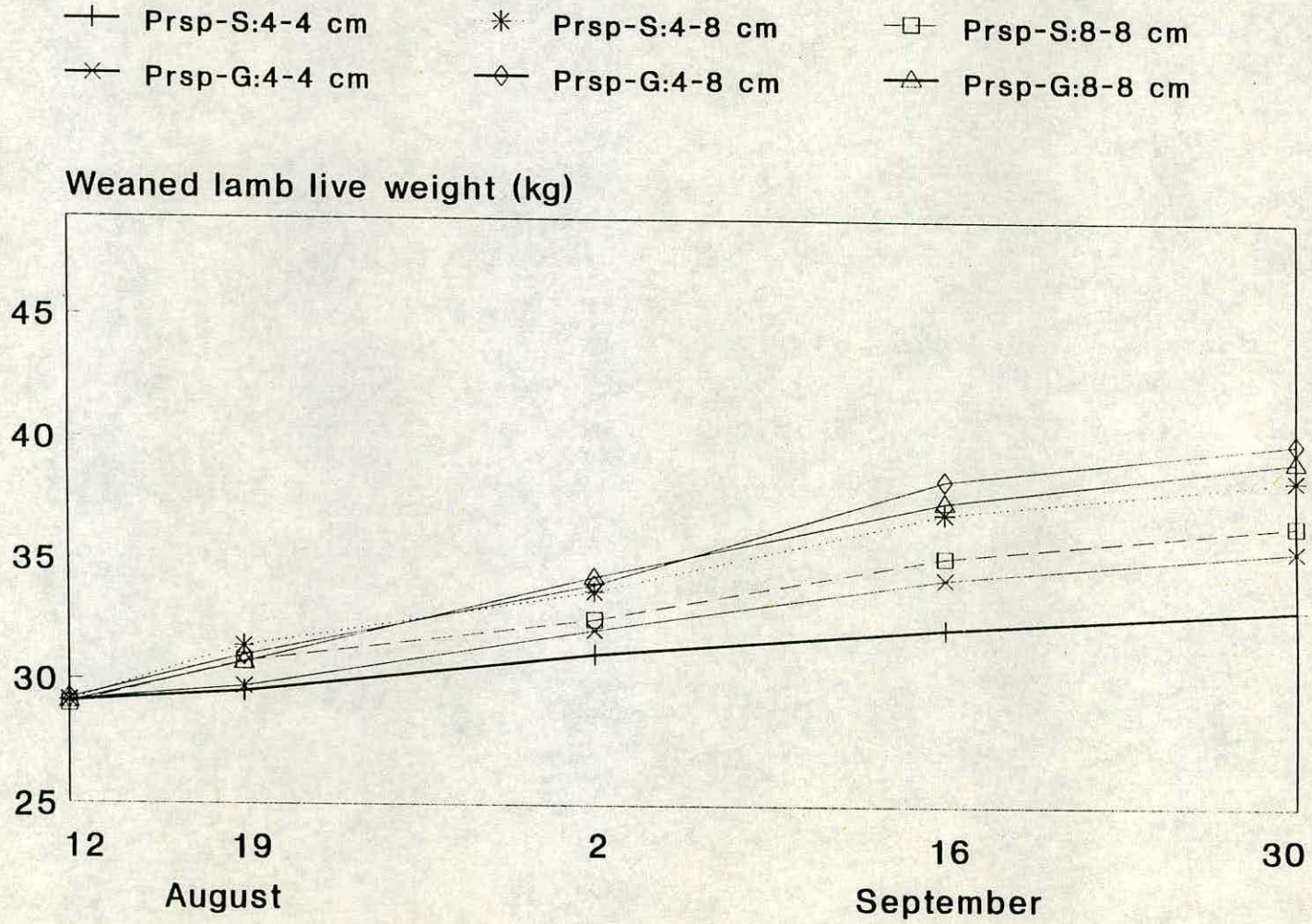
4.4.4.1.2. *Phase 2.*

Weaned lamb live weight gain is given on Table 4.16 while their live weights during Phase 2 are shown on Figure 4.18. After 17 days in Phase 2, differences in live weight gains were already significant between sward height treatments ($p<0.001$) but not between pre-species treatments. Differences between pre-species treatments became significant ($p<0.05$) by day 28 of Phase 2. Over the 49 days of Phase 2 the lambs gained more live weight on plots previously grazed by goats (187 g/day) than on plots previously grazed by sheep (141 g/day; sed. 11.8; $p<0.001$; see Table 4.16). Also lambs gained more live weight on the 4-8 cm and on the 8-8 cm treatments than on the 4-4 cm treatment (207 and 180 versus 106 g/day respectively; sed. 14.0; $p<0.001$). There was no interaction between pre-species and sward height treatments. By the end of the experiment the lambs on the Prsp-G and Prsp-S treatments weighed 38.3 versus 36.0 kg live weight respectively (sed. 0.58; $p<0.001$) and 39.2, 37.9 and 34.3 kg live weight on the 4-8 cm, 8-8 cm and 4-4 cm treatments respectively (sed. 0.69; $p<0.001$).

Table 4.16. Treatment effects on weaned lamb performance and output during Phase 2.

Pre-species (Prsp)	Sheep			Goat				Level of significance		
Sward height treatment (Height; cm)	4-4	4-8	8-8	4-4	4-8	8-8	sed	Prsp	Height	Prsp x Height
Lamb live-weight gain (g/day)(n = 10)	80	191	153	131	222	207	19.9	***	***	ns
Lamb grazing days per hectare (n = 2)	387	391	388	393	391	392	68.1	ns	ns	ns
Total lamb live-weight gain (kg/ha)(n = 2)	311	746	592	515	870	810	69.7	**	***	ns

Figure 4.18. Live weight of weaned lambs through Phase 2.



There were no differences in stocking rates of weaned lambs between pre-species treatments or height treatments (mean stocking rate ranged between 39.5 - 40.0 lambs/ha per treatment). This was reflected in similar numbers of lamb grazing days per treatment (see Table 4.16).

When weaned lamb output over the 49 days of Phase 2 was calculated, differences emerged due to both sward height treatments (808 and 701 versus 413 kg/ha on 4-8 cm, 8-8 cm and 4-4 cm treatments respectively; sed. 49.2; $p<0.001$) and between pre-species treatments (731 versus 550 kg/ha on Prsp-G and on Prsp-S respectively; sed. 40.3; $p<0.01$).

4.4.4.2. Herbage intake.

Daily herbage intakes of DM by weaned lambs during Phase 2 are presented in Table 4.17.

Lambs grazing on the Prsp-G treatment had a DM herbage intake which was 26.9% higher than that of lambs grazing on the Prsp-S treatment (1.42 versus 1.12 kg DM/day; sed. 0.064; $p<0.001$). There was a significant pre-species x sward height treatment interaction whereby the effect of pre-species was greatest on the 4-8 cm treatment and least on the 4-4 cm treatment. There were large differences in DM herbage intake between sward height treatments: 0.97, 1.66 and 1.19 kg DM/ha for 4-4 cm, 4-8 cm and 8-8 cm treatments respectively (sed. 0.078; $p<0.001$).

Finally, intake increased during Phase 2: 1.16 versus 1.38 kg DM/ha in Periods 5 and 6 respectively (sed. 0.0481; $p<0.001$).

Table 4.17. Herbage intake (kg DM/day) of weaned lambs during Phase 2 (n = 10).

Pre-species (Prsp)	Sheep			Goat				Level of significance
Sward height treatment (Height; cm)	4-4	4-8	8-8	4-4	4-8	8-8	sed[a]	
Period (Pe)								
5	0.88	1.37	0.80	0.83	1.71	1.35		Prsp ***, Height ***, Pe ***, Prsp x Height *, Prsp x Height x Pe ***
6	0.98	1.38	1.30	1.17	2.16	1.31	0.139	

([a]- sed. of means of the interaction Prsp x Height x Pe).

4.4.4.3. Diet selected.

4.4.4.3.1. *Botanical composition of the ingested diet.*

Table 4.18 shows the percentage of the five major botanical components of the diet selected by oesophageally fistulated animals during Periods 5 and 6.

Lambs grazing the Prsp-G swards selected more total clover (33.1% versus 17.6%; sed 1.83; $p<0.001$), more live clover (31.6% versus 16.9%; sed. 1.70; $p<0.001$) and more dead clover (1.5% versus 0.7%; sed. 0.24; $p<0.01$) but less total grass (65.4% versus 81.0%; sed. 1.78; $p<0.001$) and less live grass (60.9% versus 76.2%; sed. 1.79; $p<0.001$) than on the Prsp-S swards.

Also, the proportion of the components selected by the weaned lambs differed between sward height treatments. More total clover was selected from the 4-8 cm treatment than from 8-8 cm and 4-4 cm treatments: 37.6% versus 22.2% and 16.2% (sed. 2.24; $p<0.001$). Also more live clover was selected from the 4-8 cm treatment ($p<0.001$): 36.5% (4-8 cm) versus 20.6% (8-8 cm) and 15.5% (4-4 cm; sed. 2.07%) but less live grass ($p<0.001$): 56.3% (4-8 cm) versus 70.7% (8-8 cm) and 78.6% (4-4 cm; sed. 2.19). The proportion of dead grass in the diet was higher ($p<0.01$) on the 8-8 cm treatment (5.9%) compared to 4.5% and 3.7% on the 4-8 cm and 4-4 cm treatments (sed. 0.58). The proportion of dead clover was also higher on the 8-8 cm treatment (1.6%) versus 1.1% and 0.7% for the 4-8 and 4-4 cm treatments respectively (sed. 0.29; $p<0.05$).

Table 4.18. Botanical components (% DM) in the diet selected by oesophageally fistulated weaned lambs in Phase 2 (n = 12).

Pre-species (Prsp)		Sheep			Goat				
Sward height treatment (Height; cm)		4-4	4-8	8-8	4-4	4-8	8-8	sed[a]	Level of significance
Component	**Period** (Pe)								
Live grass	5	84.67	56.71	72.31	54.94	45.75	58.21		Prsp ***, Height ***, Pe ***,
	6	88.59	71.98	82.71	86.14	50.73	69.47	4.041	Prsp x Pe *, Prsp x Height x Pe ***
Dead grass	5	2.08	1.85	4.98	4.68	2.58	2.60		Height **, Pe ***, Height x Pe ***,
	6	4.43	7.58	8.26	3.46	5.92	7.77	1.121	Prsp x Height x Pe *
Live clover	5	11.62	39.76	20.37	37.98	49.23	36.66		Prsp ***, Height ***, Pe ***,
	6	4.92	17.52	7.23	7.55	39.64	18.24	3.717	Prsp x Pe *, Prsp x Height x Pe ***
Dead clover	5	0.24	0.58	1.22	1.64	1.05	1.54		Prsp **, Height *,
	6	0.65	0.81	0.81	0.21	1.97	2.87	0.539	Prsp x Height x Pe ***
Other Species	5	0.00	0.03	0.05	0.04	0.00	0.09		Height (p=0.083)
	6	0.01	0.01	0.03	0.00	0.00	0.04	0.0427	

([a]- sed. of means of the interaction Prsp x Height x Pe).

Percentages of total clover selected decreased through sampling periods ($p<0.001$) from 33.7% in Period 5 to 17.1% on Period 6 (sed. 1.37), as did the percentage of live clover ($p<0.001$). Percentages of live grass ($p<0.001$) and of dead grass ($p<0.001$) increased. The interaction between sampling periods and pre-species treatments for total clover in the diet almost reached statistical significance ($p=0.058$). Larger decreases were observed in the percentage of clover in the diet of lambs grazing the Prsp-G treatment (from 42.7% in Period 5 to 23.5% on Period 6) than in lambs grazing the Prsp-S treatment (from 24.6% in Period 5 to 10.6% in Period 6; sed. 2.29). Percentages of live clover also decreased more on the Prsp-G treatment ($p<0.05$) while the percentage of live grass increased more ($p<0.05$). The percentage of dead grass in the diet in Period 6 on the 4-8 cm and 8-8 cm treatments was much greater than in Period 5, while there was little change with time on the 4-4 cm treatment (height treatment x period, $p<0.001$).

There were highly significant ($p<0.001$) interactions between pre-species treatment, sward height treatment and sampling period for percentage of total clover selected. While on the Prsp-S:4-4 cm treatment percentage of clover in the diet decreased from 11.9% (Period 5) to 5.6% (Period 6), lambs grazing on the Prsp-G:4-4 cm treatment had a larger reduction from 39.6% (Period 5) to 7.8% (Period 6). On the Prsp-G:4-8 cm treatment percentage of total clover selected remained relatively high throughout (50.3% in Period 5 and 41.6% in Period 6) while in contrast it decreased substantially on the Prsp-S:4-8 cm treatment (from 40.3% in Period 5 and 18.3% in Period 6). The effects of pre-species treatment x sward height treatment x period on live clover were similar to those for total clover, while, as would be expected for grass and live grass, they were the opposite to that for clover.

4.4.4.3.2. *Digestibility of diet selected.*

The *in vitro* organic matter digestibility of the diet selected by the oesophageally fistulated lambs is given in Table 4.19. Lambs tended to select a diet of higher digestibility from the swards previously grazed by goats (Prsp-G) than by sheep (Prsp-S): 0.796 versus 0.786 (sed. 0.0047; p=0.058). Also, lambs selected a more digestible diet from the 4-4 cm treatment and from the 4-8 cm treatment than from the 8-8 cm treatment (0.814, 0.787, 0.772 respectively; sed. 0.0057; p<0.001).

Overall digestibility decreased from Period 5 to Period 6 (0.810 versus 0.772; sed. 0.0049; p<0.001). Larger decreases between Periods 5 and 6 were found on the 4-4 cm and 4-8 cm sward height treatments than on the 8-8 cm treatment (height treatment x period: p<0.01; see Table 4.19).

Finally the interaction pre-species x sward height treatment x period was significant (p<0.001). While decreases in digestibility between Periods 5 and 6 were similar across sward height treatments for the Prsp-S treatment, on the Prsp-G treatment there was a large decrease in digestibility on the 4-4 cm treatment, but little change on the 4-8 cm and 8-8 cm treatments.

Table 4.19. Mean *in vitro* organic matter digestibility (proportion) of diet selected by oesophageally weaned lambs (n = 12).

Pre-species (Prsp)	Sheep			Goat				
Sward height treatment (Height; cm)	4-4	4-8	8-8	4-4	4-8	8-8	sed[a]	Level of significance
Period (Pe)								
5	0.835	0.804	0.773	0.856	0.799	0.793		Prsp (p=0.058), Height ***, Pe ***, Height x Pe **, Prsp x Height x Pe ***
6	0.777	0.757	0.771	0.787	0.787	0.751	0.1169	

([a]- sed. of means of the interaction Prsp x Height x Pe).

4.4.4.4. Parasite burden.

From the analysis of faecal samples taken on weaned lambs at the end of the grazing season no evidence of fluke was found. Also, low number of eggs of *Nematodirus battus* and of *Monizia* were present in the faeces. However moderate infestation of *Trichostrongylus spp.* was found. There was a slightly heavier infestation on the Prsp-S treatment than on the Prsp-G treatment (543 versus 280 eggs/g; sed. 140.6) and 635, 435 and 165 eggs/g on 8-8 cm, 4-8 cm and 4-4 cm treatments (sed. 172.2), although there were no significant differences between either pre-species or sward height treatments.

4.4.5. The relationships between sward variables and animal variables.

4.4.5.1. Phase 1.

Regressions between the live weight changes of each animal species (ewes, lambs and goats) between Periods 1 and 2 and between Periods 2 and 3 and the mean percentage clover in the sward and on the sward surface in Periods 1 and 2 and in Periods 2 and 3 were carried out considering also sward height treatment as a potential explanatory variable.

Live weight gains of goats were negatively correlated with percentage clover in the whole sward (R^2=0.559; p=0.065) but not correlated with percentage clover on the sward surface (R^2=0.097; ns). Conversely, changes in the live weight of lactating ewes and of twin suckling lambs

were positively related with the clover percentages in the whole sward (R^2=0.456; p=0.066 and R^2=0.343; ns respectively) and on the sward surface (R^2=0.297; ns and R^2=0.504; p<0.05 respectively.

In goats, the multiple linear regression of live weight changes during Phase 1 with percentage clover in the sward surface (p<0.05) and the percentage of clover in the sward (p<0.05) was significant (R^2=0.915; p<0.05) and is given by the following parallel equations for the intervals between Periods 1 and 2 and between Periods 2 and 3:

$$y = -108.0\ (\pm\ 119.0)^a - 3.35\ (\pm\ 6.89)\ \text{sward} + 8.36\ (\pm 3.98)\ \text{surface} - 221.9\ (\pm\ 83.4)^b$$

(Equation 4.2)

where y = goat live weight changes (g/day)
sward = clover in the whole sward (%DM).
surface = clover on the sward surface (%DM).
a= intercept for interval between Periods 1 and 2
b= intercept for interval between Periods 2 and 3.

The addition of sward height treatment did not improved the fit significantly (R^2=0.944).

In ewes, in contrast, sward height treatment (p<0.001) was an important factor when added to a multiple regression including percentage clover on the sward surface (p<0.001) to explain ewe live weight changes during Phase 1 (R^2=0.975; p<0.001). The equation was:

$$y = -232.5\ (\pm\ 25.7)^a + 3.72\ (\pm\ 1.15)\ \text{surface} - 54.7\ (\pm\ 20.5)^b$$

(Equation 4.3)

where y = ewe live weight changes (g/day)
surface = clover on the sward surface (%DM).
a= intercept for the 4 cm sward height treatment
b= intercept for the 8 cm sward height treatment.

Also in lambs, the multiple linear regression of percentage of clover on the sward surface ($p<0.05$) and sward height treatment (ns) explained most variation in live weight gains in lambs ($R^2=0.725$; $p<0.05$) and the equation is given below:

$$y = 57.5\ (\pm\ 69.6)^a + 6.66\ (\pm\ 3.10)\ surface$$
$$139.8\ (\pm\ 55.3)^b$$

where y = lamb live weight changes (g/day)
surface = percentage of clover on the sward surface (DM).
a= intercept for the 4 cm sward height treatment
b= intercept for the 8 cm sward height treatment

(Equation 4.4)

4.4.5.2. Phase 2.

Linear regressions were carried out to study the relationships between live weight gain, herbage intake and percentage clover selected by weaned lambs and a set of variables measured on the sward. The overall correlation matrix is given in Table 4.20.

Table 4.20. Correlation matrix for some of the key variables during Phase 2 (n=12).

	live weight gain (g/day)	daily intake (kg DM/day)	clover in the diet (%)	clover in the sward (%)	clover in the sward surface (%)	diet OM digest-bility (%)	herbage mass (kg DM/ha)
live weight gain (g/day)	1.000						
daily intake (kg DM/day)	0.664*	1.000					
clover in the diet (%)	0.545	0.512	1.000				
clover in the sward (%)	0.616*	-0.111	0.668*	1.000			
clover in the sward surface (%)	0.734**	-0.027	0.743**	0.929***	1.000		
diet OM digest-bility (%)	-0.407	-0.265	0.366	0.722**	0.572*	1.000	
herbage mass (kg DM/ha)	0.613*	0.876***	0.206	-0.469	-0.386	-0.560	1.000

4.4.5.2.1. *The relationship between diet quality and sward composition.*

Figure 4.19 shows the relationships between the percentage clover selected in the diet by weaned lambs and the percentage of clover found in the whole sward and in the sward surface through both sampling periods (Periods 5 and 6). The percentage clover in the diet was more closely related to the percentage clover on the sward surface than in the whole sward (see Table 4.20) as can be seen from the following equation:

$$y = 0.91 (\pm 7.67) + 1.19 (\pm 0.34) \text{ surface}; R^2=0.551; p<0.01$$

$$y = -4.20 (\pm 11.0) + 1.50 (\pm 0.53) \text{ sward}; R^2=0.446; p<0.05$$

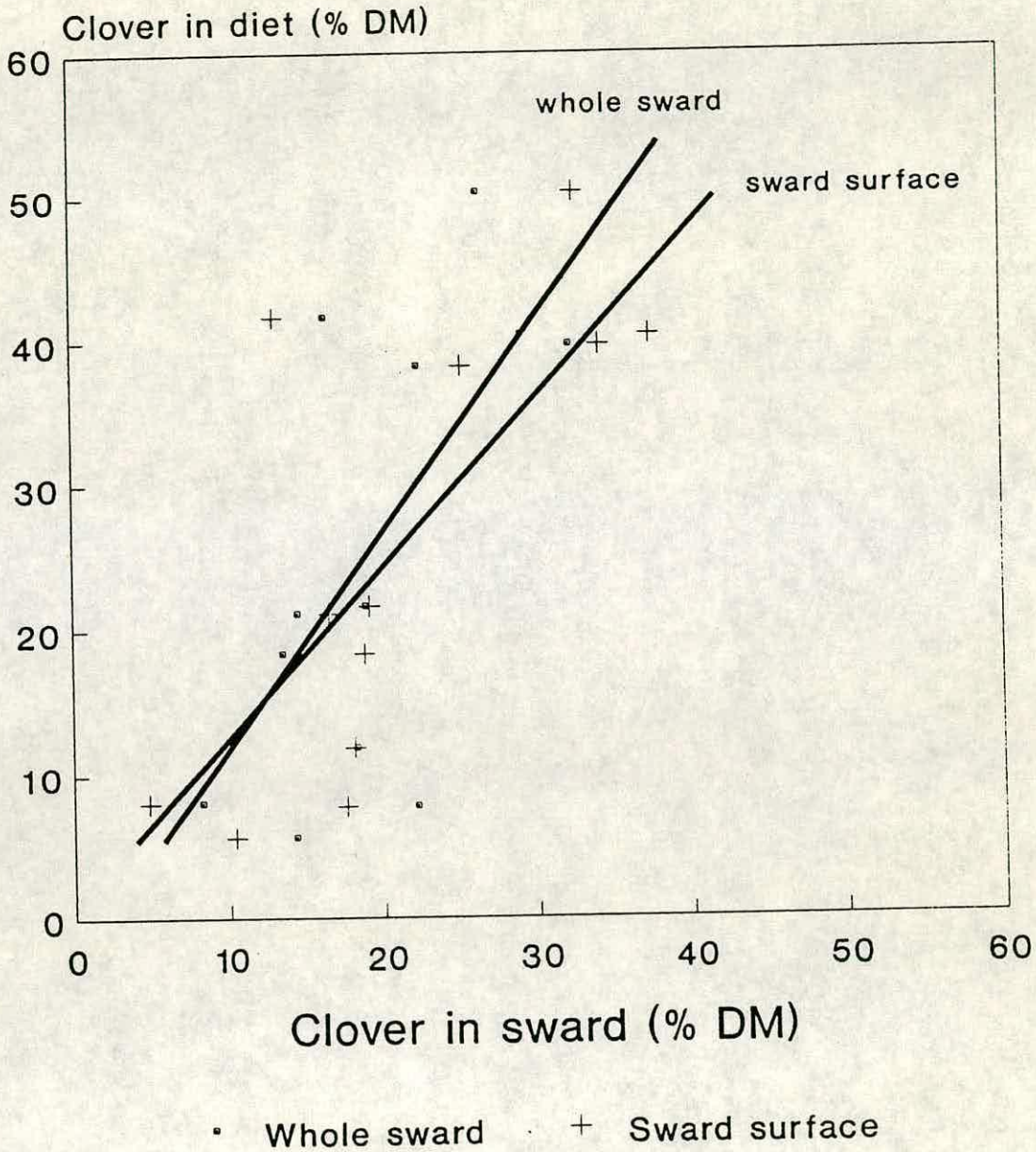
where y = clover in diet (%DM)
surface = clover in sward surface (%DM)
sward = clover in sward (%DM).

(Equation 4.5)

The addition of sward height treatment ($p<0.05$) and pre-species treatment ($p<0.05$) increased the amount of variation explained ($R^2=0.920$; $p<0.01$).

The organic matter digestibility of the diet was not related to the percentage clover in the diet ($R^2=0.134$; ns; see Table 4.20).

Figure 4.19. Relationships between percentage clover in the diet selected by lambs and percentage clover in the whole sward and on the 'sward surface'.



4.4.5.2.2. *The relationships between herbage intake, sward composition and diet quality variables.*

Figure 4.20 shows the linear relationships between daily herbage intake by the weaned lambs with percentage clover on the diet (a), organic matter digestibility of the diet (b) and herbage mass (c).

Correlation between daily herbage intake and percentage of clover in the diet was not significant (R^2=0.262; p=0.089):

$$y = 0.95\ (\pm\ 0.20) + 0.01\ (\pm\ 0.006)\ diet$$

where y = herbage intake (kg DM/day)
diet = clover in diet (%DM)

(Equation 4.6)

There was no relationships between herbage intake and the percentage clover in the whole sward (R^2=0.123; ns) or on the sward surface (R^2=0.007; ns) neither was there a significant correlation between diet digestibility and herbage intake (R^2=0.007; ns).

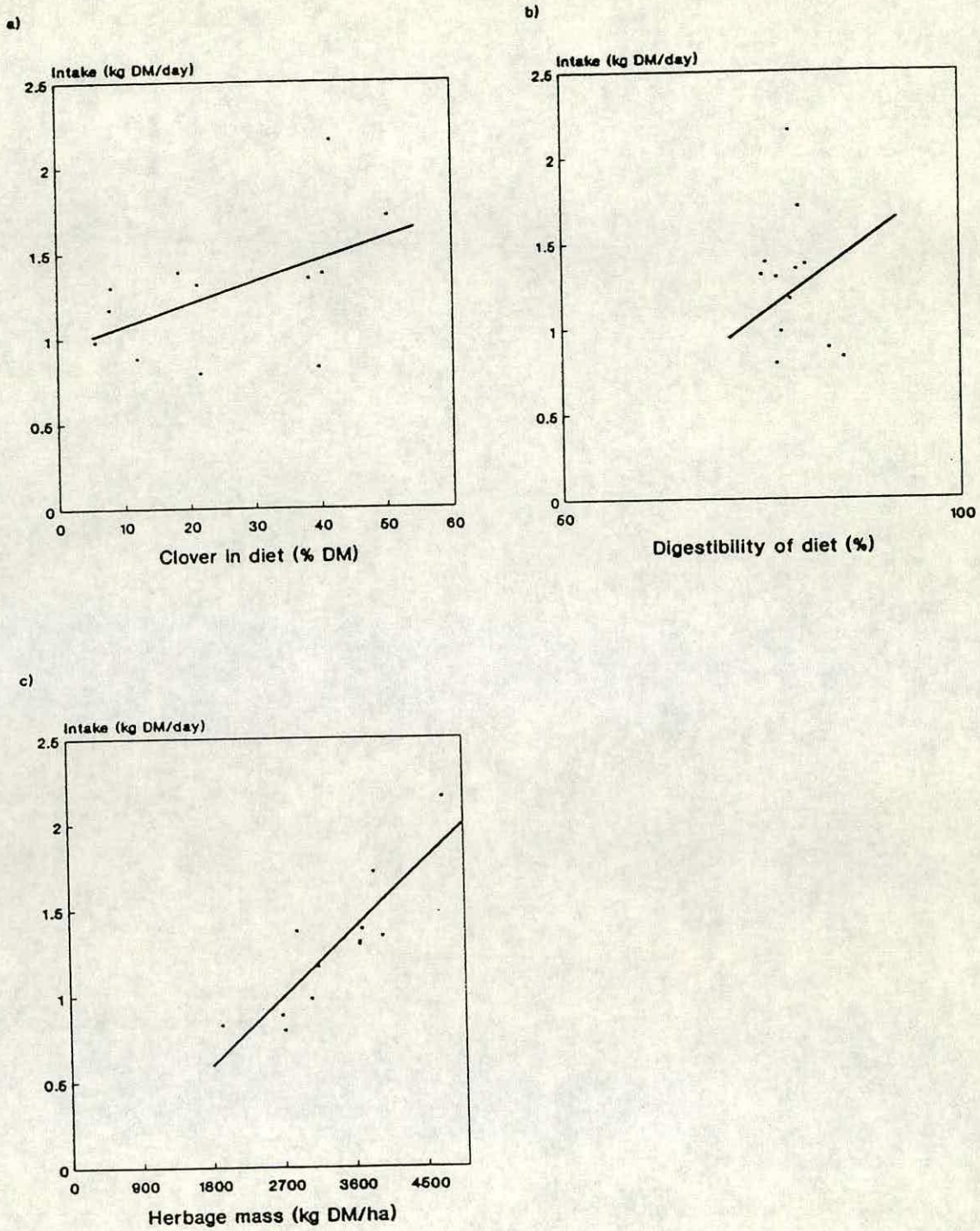
Herbage intake was related with herbage mass (R^2=0.767; p<0.001) by the following equation:

$$y = -0.26\ (\pm\ 0.27) + 0.00123\ (\pm\ 0.000117)\ herbage\ mass$$

where y = herbage intake (kg DM/day)
herbage mass = herbage mass (kgDM/day)

(Equation 4.7)

Figure 4.20. Relationships of lamb herbage intake with a) percentage clover on diet selected, b) organic matter digestibility of the diet selected and c) sward herbage mass during Phase 2.



The addition of sward height treatment as a factor ($p<0.05$) improved significantly the regression ($R^2=0.914$; $p<0.001$) and the equation is given below:

$$y = -0.08\ (\pm\ 0.27)^{a} + 0.00134\ (\pm\ 0.000127)\ \text{herbage mass} + 0.19\ (\pm 0.16)^{b} - 0.17\ (\pm 0.16)^{c}$$

where y = herbage intake (kg DM/day)
herbage mass = herbage mass (kgDM/day)
a=intercept for the 4-4 cm sward height treatment
b=intercept for the 4-8 cm sward height treatment
c=intercept for the 8-8 cm sward height treatment

(Equation 4.8)

When herbage intake was related to percentage clover in the whole sward, in the sward surface, percentage clover in the diet, diet digestibility, sward herbage mass using a step-wise multiple linear regression, the model that accounted for the highest percentage of variation explained in the intake rate had herbage mass ($p<0.001$) and percentage of clover in the whole sward ($p<0.05$) as explanatory variables ($R^2=0.882$; $p<0.001$):

$$\text{where } y = -0.99\ (\pm\ 0.32) + 0.00145\ (\pm\ 0.000168)\ \text{herbage mass} + 0.02\ (\pm 0.007)\ \text{sward}$$

where y = herbage intake rate (kg DM/day)
herbage mass = herbage mass (kgDM/day)
sward = clover in the whole sward (%DM)

(Equation 4.9)

4.4.5.2.3. *The relationships between lamb performance, sward composition and diet quality variables.*

The relationship between weaned lamb live weight gain and percentage clover in the whole sward and in the sward surface are displayed in Figure 4.21. Lamb live weight gains (g/day) and consequently lamb output (kg/ha) were more strongly related to the percentage of clover in the sward surface (R^2=0.538; p<0.001 for both regressions):

$$y = 59.8 (\pm 22.7) + 3.9 (\pm 0.78) \text{ surface}$$

$$z = 203.0 (\pm 112.0) + 16.6 (\pm 3.97) \text{ surface}$$

where y = weaned lamb live weight gain (g/day)
z = weaned lamb output (kg/ha)
surface = clover on sward surface (%DM)

(Equation 4.10)

than with the percentage of clover in the sward (R^2=0.380; p<0.01):

$$y = 55.7 (\pm 31.7) + 4.7 (\pm 1.27) \text{ sward}$$

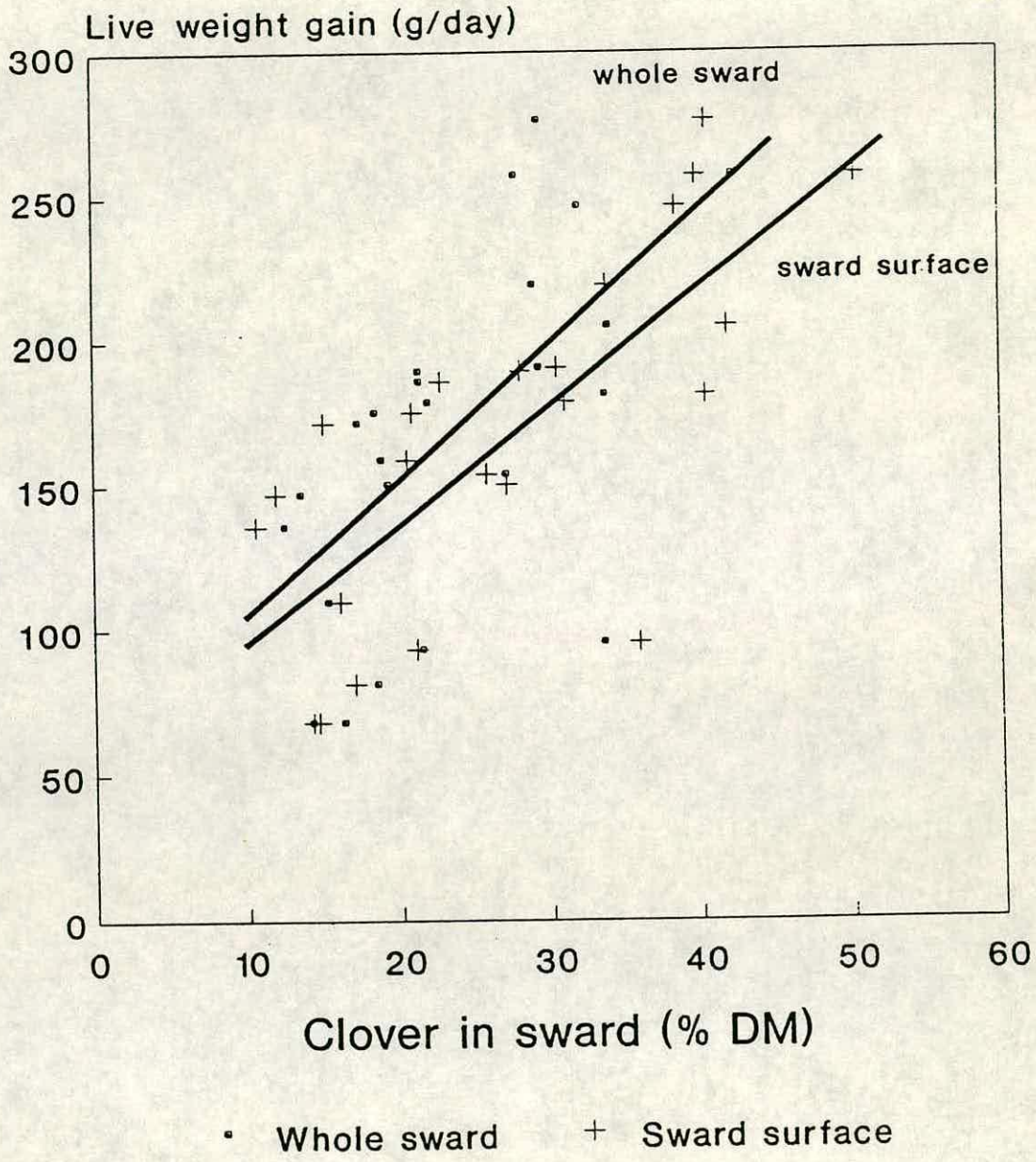
$$z = 168.0 (\pm 174.0) + 20.1 (\pm 7.12) \text{ sward}$$

where y = weaned lamb live weight gain (g/day)
z = weaned lamb output (kg/ha)
sward = clover in the whole sward (%DM)

(Equation 4.11)

Live weight gain was related to percentage clover in the diet by the equation 4.12 (R^2=0.297; p=0.067):

Figure 4.21. Relationships of lamb live weight gains and percentage of clover in the whole sward and on the 'sward surface'.



$$y = 111.9\ (\pm\ 24.3) + 1.7\ (\pm\ 0.82)\ diet$$

where y = weaned lamb live weight gain (g/day)
diet = clover in the diet (%DM)

(Equation 4.12)

When sward height treatment ($p<0.01$) and sampling period ($p=0.059$) terms were introduced as explanatory factors for live weight changes the regression became significant ($R^2 = 0.751$; $p<0.05$).

All these results clearly indicated that sward height treatment had a dominant effect on the lamb live weight changes and as a consequence on the lamb output per hectare.

Weaned lamb live weight changes were significantly related to herbage intake ($R^2=0.441$; $p<0.05$; see Figure 4.22):

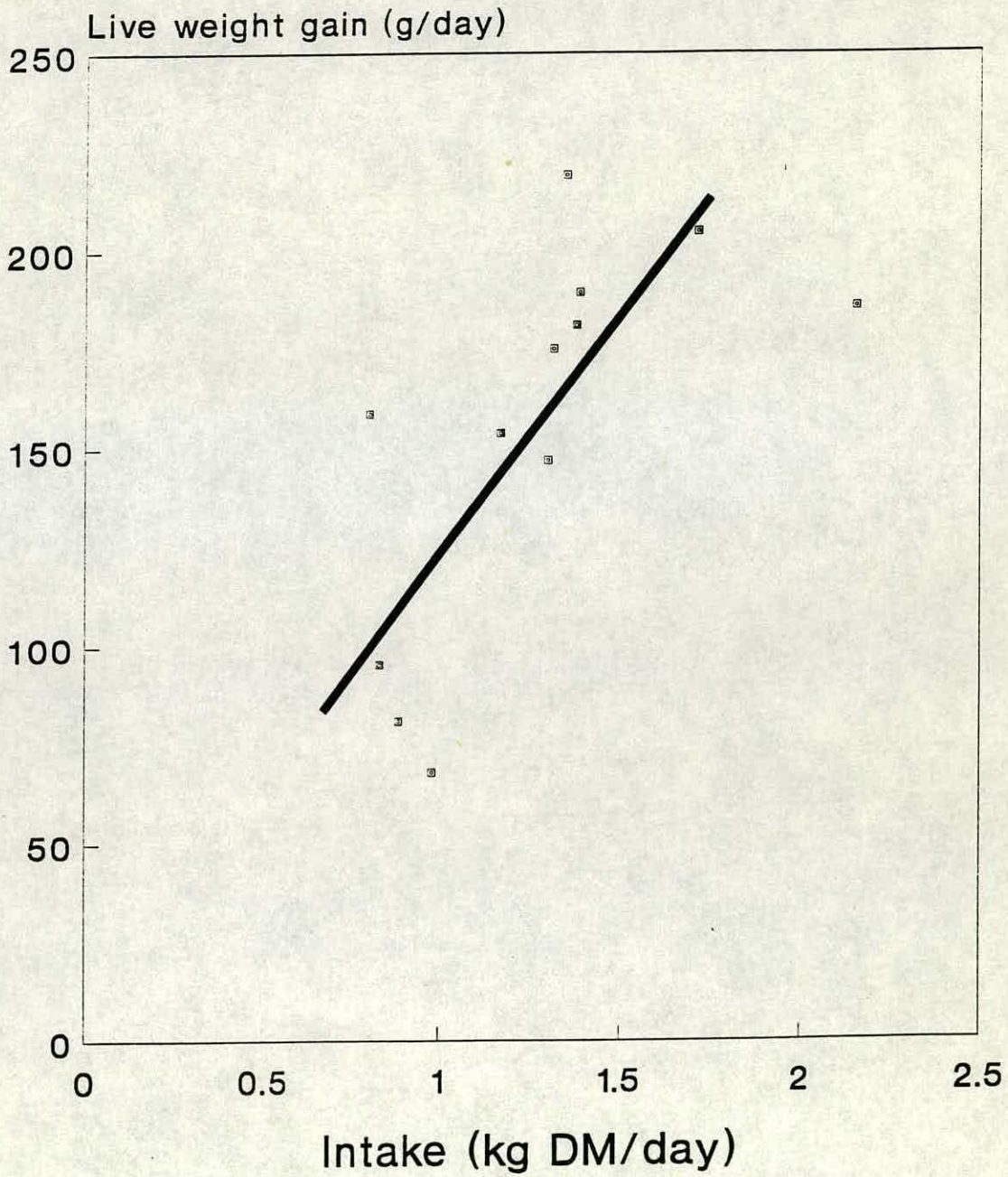
$$y = 48.7\ (\pm\ 39.4) + 83.6\ (\pm\ 29.7)\ intake$$

where y = weaned lamb live weight gains (g/day)
intake = herbage intake rate (kgDM/day)

(Equation 4.13)

Finally, the simplest significant multiple regression model that accounted for as much as possible of the variation ($R^2=0.754$; $p<0.01$) on lamb live weight gain from all the variables given in Table 4.20 was:

Figure 4:22. Relationship between lamb live weight gains and herbage intake during Phase 2.



$$y = 814.0\ (\pm\ 286.0) + 64.7\ (\pm\ 23.2)\ intake + 3.09\ (\pm 1.1)\ surface - 1018.0\ (\pm\ 364.0)\ digestibility.$$

where y = weaned lamb live weight gain (g/day)
intake = herbage intake (kg DM/ha)
surface = clover on sward surface (%DM)
digestibility = organic matter digestibility of diet (proportion)

(Equation 4.14)

4.5. Discussion.

The experiment was concerned with the effect of grazing with one animal species (sheep or goats) on the subsequent diet selected, herbage intake and animal performance of weaned lambs and also with the effect of the interaction between these animal species and sward height on the balance between grass and clover in the sward. Therefore, initially, Sections 4.5.1, 4.5.2 and 4.5.3 will deal respectively with responses through the season, sward height and herbage mass. Afterwards, Section 4.5.4 considers sward and animal responses through both Phases of Experiment 2. Finally Section 4.5.5 will summarise the main findings.

4.5.1. Seasonal effect on the sward.

In Phase 1 maximum clover mass was achieved in July (582, 721 and 787 kg/ha in Periods 1, 2 and 3 respectively; $p<0.05$) while the grass mass was relatively constant (1998, 2056 and 1982 kg/ha in Periods 1, 2 and 3 respectively). The change in clover mass is similar to previous reports (Barthram and Grant, 1994) and reflects the increase in

temperature throughout Phase 1.

4.5.2. Sward height heterogeneity.

Although the initial difference in the mean sward height between pre-species treatments on the 8 cm sward height treatment was reflected in a higher average sward height during Phase 1 in the Prsp-G treatment (+0.9 cm) the difference was not significant. The mean sward heights for the 4 and 8 cm treatments were maintained successfully throughout Phases 1 and 2 inside the range 4 $\pm$ 1.0 cm and 8 $\pm$ 1.0 cm respectively. Consequently as in Experiment 1, it was possible to compare the effect of sheep and goat grazing treatments on the frequency distribution of the measurements of the sward surface heights during Phases 1 and 2.

As in Experiment 1, on both height treatments during Phase 1, goat-grazed paddocks had a greater degree of skewness in sward height measurements than sheep-grazed paddocks. This does not agree with the results of Collins and Nicol (unpublished data, cited by Nicol *et al.*, 1987) who suggested that the spatial pattern of grazing of sheep resulted in a greater patchiness in ryegrass/white clover swards than with goats. However they recognised that the sward height to which their animals were grazing on a rotational system was perhaps more limiting to the intake of goats than sheep. In the current study the goat's supposedly browsing habit of grazing the top of the sward, produced a greater number of taller sward surface height measurements. The effect became clearer at higher sward heights i.e. the differences were greater on the 8 cm height treatment ($p<0.001$) than on the 4 cm height treatment ($p<0.05$).

During Phase 2 the differences in distribution of sward height measurements created by pre-species treatment in Phase 1 still remained on the 4-4 cm and 8-8 cm height treatment but not on the 4-8 cm treatments. The lack of a carry-over effect on this last treatment was due probably to the rest period between Phases 1 and 2. In contrast to Phase 1, the shorter sward height treatment (4-4 cm) displayed greater differences between pre-species treatments (Prsp-G and Prsp-S) than on the 8-8 cm sward height treatment. As Hepp-Kuschel (1989) suggested, because of their smaller bite size, lambs probably had smaller grazing depths than ewes and goats and they may have concentrated mainly on the sward surface of the 8-8 cm height swards while they may have grazed down to a similar height on the 4-4 cm height sward avoiding the pseudostem layer of the swards.

4.5.3. Herbage mass.

As expected, sward height treatments had different herbage masses. The 4 cm height treatment had significantly lower herbage mass than the 8 cm height treatment at the end of Phase 1 ($p<0.01$) and whilst the 4-8 cm and 8-8 cm height treatments had similar herbage masses, the 4-4 cm height treatment had significantly lower herbage mass during Phase 2 ($p<0.001$).

Swards allowed to increase in height from 4 cm to 8 cm sward height during the transitional period between Phases 1 and 2 increased dramatically in clover content (+385 kg DM/ha) while their grass content decreased (-224 kg DM/ha). A similar response was seen by Grant and Barthram (1990)

and Barthram and Grant (1994) in the same environmental conditions. In their work a rest period affected the balance between clover and ryegrass in the sward with the actual changes depending on the timing of release from grazing. They recorded that the white clover content of the sward was increased by a period of herbage accumulation from 4-5 cm to 7.5 cm sward height in May and June rather than in April and May where the white clover content of the sward was reduced in favour to ryegrass. As a consequence, the time of the rest period in the middle of the summer (22 July - 12 August) allowing the sward to grow to 8 cm when temperatures were higher favoured the white clover with respect to the ryegrass. Barthram and Grant (1994) related this to the advantageous position occupied by clover laminae with respect to ryegrass within the sward canopy.

Pre-species treatments did not result in significant differences in overall herbage mass during either Phase 1 or 2.

4.5.4. Relationships between animal responses and sward composition.

4.5.4.1. Effect of animal species on sward composition.

From Period 1, at the beginning of the experiment, to Period 3, at the end of Phase 1, the overall percentage of clover in the sward of goat-grazed swards (Prsp-G) increased (+15.8%), whereas in the sheep-grazed swards (Prsp-S) it decreased (-3.9%; $p<0.001$). This agrees well with the work of Bown *et al.* (1989) who reported on goat-grazed swards, an increase in clover of around 15% over the grazing season. This resulted at the end of Phase 1, in

higher live clover masses within horizon on the Prsp-G treatment than on the Prsp-S treatment ($p<0.1$; see Figure 4.11) and coincided with a visually denser appearance of clover with apparently taller clover units on the goat-grazed swards (see Plates 4.1a and 4.1b). It was shown in Experiment 1 that sheep eat white clover in higher proportion to that on offer than goats providing an explanation for the higher clover content in pastures grazed by goats in the present study. The lower consumption of clover by goats was reflected in higher accumulations of dead clover mass in the Prsp-G treatment than in the Prsp-S treatment especially near to ground level in the horizon 0-2 cm. Also this was reflected during Phase 1 in significantly higher increases in clover masses within the horizon nearest to the ground level (0-2 cm) in the swards grazed by goats in contrast with decreases in the swards grazed by sheep which suggested that higher amounts of clover stolons were removed from swards grazed by sheep. This was also seen in Phase 2 of Experiment 1 and agrees with Townsend and Radcliffe (1990) who recorded under a mixed goat and sheep regime, higher clover masses than under a single sheep regime.

These differences between pre-species treatments in the percentage clover in the whole sward during Phase 1 were even more dramatic on the sward surface. Goat-grazed paddocks showed an increase in percentage clover from 35.3% in Period 1 to 43.0% in Period 3, while on sheep-grazed paddocks there was a decrease from 38.1% in Period 1 to 17.8% in Period 3. This suggests, as seen in Experiment 1, that the composition of the diet in both sheep and goats were closely related to changes occurring on the upper layers of the sward.

Plate 4.1- Swards during Phase 1.

a) Left: Grazed by sheep at 8 cm
Right: Grazed by goats at 4 cm



b) Left: Grazed by sheep at 8 cm
Right: Grazed by goats at 8 cm



4.5.4.2. Ewe, lamb and goat performance in Phase 1.

There was a trend of higher goat live weight gains (+43.3 g/day) and higher body condition score on the 8 cm sward height treatment than on the 4 cm sward height treatment. Although these gains were lower than the live weight gains of Angora goats found by Stevens *et al.* (1992) at similar herbage masses (126 g/day) they were similar to the live weight gains of 54-92 g/day and 49 g/day found by Bown *et al.* (1989) and Townsend and Radcliffe (1990) respectively in Angora goats. Although the 'average' stocking density between height treatments was not significantly different, the total live weight output was 314 kg/ha higher on the 8 cm paddocks than on the 4 cm paddocks (see Table 4.13). Radcliffe *et al.* (1991) suggested that taller swards with a higher clover lamina-petiole mass produced by goat grazing, probably enhanced goat growth rates due to the fact that goats grazing alone showed a greater consumption of clover than goats grazing with sheep and consequently the higher proportion of clover in the diet would have provided better nutrition. However it is more probable that the lower performance at 4 cm sward height was probably caused by a reduction in herbage intake related to lower masses of green grass leaf recorded in the upper layers. Hughes *et al.* (1984) and Lu (1988) also measured reductions in the goats' herbage intake when proportion of green leaf fell in sown swards and Merchant and Riach (1994) suggested green leaf availability is an important determinant of herbage intake by goats. Conversely, goat live weight gains were negatively correlated with the percentage of clover in the whole sward and with the percentage clover on the sward surface (Equation 4.2).

The results confirm that pasture height has an

important influence in goat productivity in a goat-only grazing system as previously seen by Merchant and Riach (1994). Additionally, the castrate goats tended to lose live weight and body condition score through the second part of Phase 1 on the 8 cm sward height treatment. A similar pattern has also been observed with castrate goats by Margaret and Riach (1994) which could be due to the fact that the live weights achieved during Phase 1 were near to the goats' mature weight.

Sward height treatment also affected ewes' and lambs' live weight changes. Ewes lost 122 g/day on the 4 cm sward height treatment but gained 101 g/day on the 8 cm sward height treatment. Similarly only small increases in ewes' body condition were found on the 8 cm sward height treatment but ewes lost body condition on the 4 cm sward. Their suckling lambs also grew significantly better on the 8 cm treatment than on the 4 cm treatment (326.5 versus 215.0 g/day; $p<0.05$; see Table 4.14). This suggests that the capacity of twin rearing ewes to consume pasture at 4 cm was restricted, similar to the findings of Parker and McCutcheon (1992) on swards at 3.5 cm. Chestnutt (1992) working on grass/clover swards at 3, 5, 7 and 9 cm also reported an increase in suckling lamb growth rates with increased sward height with the highest growth rate occurring when swards were grazed at 9 cm. The short sward in the Prsp-S:4 cm treatment probably limited the potential for intake by limiting the physical capacity to harvest feed and by having during Periods 2 and 3 more dead grass near to the ground level (0-2 cm) as illustrated in Figure 4.10. Penning *et al.* (1991a) recorded an optimum sward surface height between 3 cm and 6 cm for lactating ewes grazing with twin lambs and Orr *et al.* (1990) also found a maximum performance of non-lactating sheep at 6 cm sward height. They claimed that swards above 6 cm continuously stocked by sheep would deteriorate in structure, but since

they had sward height treatments of 3, 6 and 9 cm, the exact height at which structure deteriorates between 6 and 9 cm could not be defined. However, in the current study, there was a greater increase in dead material on the 4 cm than on the 8 cm sward height treatment (25.6% versus 9.0% respectively at the end of Phase 1; Table 4.7), which does not support the contention that higher sward heights initially lead to deterioration in quality.

A gradual decline of the ewe live weight gains recorded after 14 days in both height treatments may be associated with an overall increase in dead grass in all horizons at both sward heights as also recorded by Forbes (1982) and therefore with a decrease in their herbage intake as recorded by Gibb and Treacher (1980) in lactating ewes after 3 weeks on pasture. But as Rattray, Thompson, Hawker and Sumner (1987) mentioned sheep live weight gains could be influenced considerably by gut fill changes. They recorded in lactating ewes which were changed from low to a high intake, gut fill increases of over 5 kg and therefore this can lead to over-estimates of ewe live weight change by 50%, particularly if live weight gain is calculated over a short period. Nevertheless, the ewe live weight changes were more responsive to sward height than were lamb live weight gains. This was probably due to the fact that lambs are buffered to a large extent from the effects of sward height because of the milk supplied by their mothers. However both the ewes' and the lambs' live weight changes were significantly related with the percentage of clover present on the sward surface (Equations 4.3 and 4.4), and in the case of lambs this may reflect either a direct effect of more clover in the lambs' diet or an increase on the ewes' milk yield as a consequence of more clover in the diet of the ewes (Gibb and Treacher, 1983).

Although stocking density of ewes and lambs was higher on the 4 cm sward height treatment ($p<0.05$ and $p<0.05$ respectively), the total live weight output per hectare was higher on the 8 cm sward height treatment than on the 4 cm sward height treatment (+450.3 kg/ha; $p<0.01$) because of higher individual animal performance.

4.5.4.3. Effect of sward composition on weaned lamb responses.

4.5.4.3.1. *Effect of sward composition on diet composition.*

The higher proportion of clover found in the diet of the lambs compared to that in the sward provides evidence of selective grazing for clover as has traditionally been reported in lambs (Jamieson and Hodgson, 1979b; Hughes *et al.*, 1984; Hepp-Kuschel, 1989; Hughes, 1990; Armstrong *et al.*, 1993).

During Phase 2 there was an overall decrease in the percentage of clover in the swards although there was more clover in most horizons in plots previously grazed by goats (Prsp-G) than in plots previously grazed by sheep (Prsp-S) as illustrated in Figure 4.15. These differences were more dramatic on the sward surface (see Plates 4.2a and 4.2b). Since swards previously grazed by goats during Phase 1 had higher percentages of live clover on the sward surface than plots previously grazed by sheep in both sampling periods ($p<0.05$ in Period 6), lambs selected more live clover from the Prsp-G treatment than from the Prsp-S treatment ($p<0.001$).

Plate 4.2- Swards during Phase 2.

a) Left: Pasture previously grazed by sheep at 4cm and grazed by lambs at 4 cm (treatment Prsp-S:4-4 cm).

Right: Pasture previously grazed by goats at 8 cm and grazed by lambs at 8 cm (treatment Prsp-G:8-8 cm).



b) Left: Pasture previously grazed by sheep at 8 cm and grazed by lambs at 8 cm (treatment Prsp-S:8-8 cm).

Right: Pasture previously grazed by goats at 4 cm and grazed by lambs at 8 cm (treatment Prsp-G:4-8 cm).



This agrees well with the findings of Townsend and Radcliffe (1990). They found that faecal samples from lambs rotationally grazing with goats and sheep showed a significant increase in the proportion of clover in the diet as the goat:sheep ratio increased.

Plots allowed to grow from 4 cm to 8 cm had the highest percentage clover on the sward surface and lambs grazing from them had the highest proportion of clover in their diets. This also showed the greater accessibility of the clover green material in the 4-8 cm sward height treatment than in other sward height treatments. Wright *et al.* (1992) also found higher percentages of clover on lamb-grazing swards allowed to grow from 4 cm to 8 cm and previously grazed by cattle or sheep.

These variations in the percentage clover ingested by lambs were more closely related in both sampling periods to the percentage clover present on the sward surface than present in the whole sward (see Equation 4.5). Therefore, as the percentage of clover in the sward surface decreased on both the Prsp-G treatment (-24.3%) and the Prsp-S treatment (-14.1%) from Period 4 to Period 6, the percentage of clover ingested by lambs decreased throughout Phase 2. This suggests, as indicated by Armstrong *et al.* (1993) in their work with weaned lambs grazing grass/clover swards, that the decline over time in the proportion of clover in the diet on the lambs could be due to a declining opportunity for selection as the percentage of live clover on the sward surface was reduced, more markedly on the Prsp-G treatment (-31.9% on the Prsp-G:4-4 cm treatment and -17.1% on the Prsp-G:8-8 cm treatment) than on the Prsp-S treatment although there was also a large decrease on the Prsp-S:4-8 cm treatment (-22.0%).

Additionally, the percentage dead grass ingested by

lambs was higher from the 8-8 cm sward height treatment than from the 4-4 cm and 4-8 cm sward height treatments. This matched with the higher values of percentage dead grass (20.0 and 42.6% in Periods 5 and 6 respectively) present on the sward surface of the Prsp-S:8-8 cm treatment but not with the lower values (7.7% and 7.1% in Periods 5 and 6) present on the sward surface of the Prsp-G:8-8 cm treatment. This agrees well with the results of Bircham and Hodgson (1983) who recorded increases with time in the proportion of dead material in swards grazed by sheep particularly in tall swards associated with higher rates of senescence. Nonetheless, the average percentage dead grass ingested by the lambs in both sampling periods was much lower than the 18.0% consumed by the weaned lambs in the work of Hughes *et al.* (1984).

4.5.4.3.2. *Effect of sward composition on diet digestibility.*

Animal species in Phase 1 influenced the OM digestibility of the diet selected by lambs. Lambs grazing plots previously grazed by goats selected a diet of higher digestibility. These differences in diet quality may arise from differences of composition in the upper layers between animal species treatments. During Periods 5 and 6, lambs found in the upper layers (4-6 cm and >6 cm horizons) from the goat-grazed swards higher green herbage mass levels (live grass plus live clover) than from the sheep-grazed swards. Also, in their mixed rotational grazing study, Townsend and Radcliffe (1990) recorded higher residual green herbage masses in the lamb-grazing swards with higher goat:ewe ratios.

Moreover, the different sward height treatments

affected the digestibility of the diet selected by lambs. As Hepp-Kuschel (1989) suggested higher contents of dead reproductive stem present on the sward surface of the plots previously grazed by sheep and on swards maintained at 8 cm (8-8 cm sward height treatment) could exert more difficulty in forage prehension by the lamb's small bites while in the swards maintained at 4 cm (4-4 cm sward height treatment) the pseudostem layer may present a barrier to the grazing lamb (Barthram, 1981) and consequently the lamb's herbage intake seems to be affected markedly at low heights (Hepp-Kuschel, 1989). Also, diets selected from the 4-4 cm and 4-8 cm sward height treatments had higher OM digestibility than those selected from the 8-8 cm sward height treatment. This contrasts with the results of Hodgson (1981) and Hepp-Kuschel (1989) who found that lambs ingested herbage with higher organic matter digestibility from tall swards compared to short swards.

In the current study, the organic matter digestibility of the diet was poorly related to the percentage clover in the diet and, although decreases in the digestibility of the diet selected through Phase 2 may be related to decreases in the availability of clover in the whole sward and on the sward surface (particularly on the Prsp-G:4-4 cm treatment), it seems likely that the amount of live grass lamina selected in the diet might also heavily influence the digestibility of the diet. As Hughes *et al.* (1984) saw on his work, there is a tendency for younger grass leaves to be located nearest to the top of the sward on the 4-4 cm sward and consequently this may have favour the shallow grazing habits of the lambs. This is supported by the higher proportion of live grass seen in the lamb's diets ingested from the 4-4 cm treatment plots when compared to that ingested from the 8-8 cm treatment plots.

4.5.4.3.3. *Effect of sward composition on animal intake and performance.*

Animal species in Phase 1 also affected lambs' herbage intake and consequently their performance. Lamb-grazed plots previously grazed by goats had higher herbage intakes than those on plots previously grazed by sheep and then gained more live weight (+45.5 g/day). Other workers (Radcliffe and Francis, 1988; Townsend and Radcliffe, 1990) have already suggested the possibility of goats facilitating grazing by lambs. Townsend and Radcliffe (1990) reported lamb growth rates of 152 g/day in sheep-grazed swards and 169, 185 and 203 g/day under mixed sheep-goat grazing systems with ewe:goat ratios of 3:1, 3:2 and 3:3 respectively and this was related, as seen in the current study, to increases from 30% to 60% of white clover in the pasture as the proportion of goats:ewes increased. Their results also pointed to lower pasture clover contents on the diet as being a major factor responsible for lower lamb live weight gains observed. Radcliffe and Francis (1988) recorded in weaned lambs, rotationally grazing, live weight gains of 160, 149 and 142 g/day in pasture which were grazed by goats-only, goats/sheep and sheep-only the preceding spring. Thus both studies, although using different grazing regimes to the present experiment, support the idea of enhancement of clover under goat grazing and suggest that significant improvements can be achieved in lamb intake and performance. However, in contrast to the New Zealand experience, Nicol *et al.* (1993) found no increase in individual live weight gains of sheep or cattle when grazing with yearling goats at 4 or 8 cm and at 8 or 12 cm sward height respectively. It might be possible that in the experiment of Nicol *et al.* (1993) conducted in the UK, there was not enough clover for the mixes of sheep or cattle with goats to have a beneficial

effect. Similarly in the current study, the absence of a significant correlation between herbage intake and percentage clover in the diet of lambs (Equation 4.6; see Table 4.20) as found with sheep by Clark and Harris (1985), suggests a different set of grazing decisions taken by the lambs (higher herbage mass and higher percentage clover in the whole sward as seen in the Equation 4.9) when confronted with different sward structures.

Lambs on the 4-8 cm sward height treatment had higher herbage intakes than on the 4-4 cm and 8-8 cm sward height treatments respectively as herbage intake increased with higher herbage mass and higher percentage clover in the whole sward (Equation 4.9). This agrees well with the work of Hepp-Kuschel (1989) who recorded lower herbage intakes on lambs grazing sown swards at 4 cm than at 8 cm sward heights and this was associated with a decrease in the lamb bite sizes and also with the guidelines produced by Maxwell and Treacher (1987) who emphasized the need to increase sward height to about 8 cm in late summer to ensure that there is sufficient green leaf present to minimize decline intake as sward structure is deteriorated.

There was a significant increase on the amount of herbage ingested from Period 5 to Period 6. This was expected as herbage intake by the lambs was significantly related to herbage mass during Phase 2 (see Equation 4.8) as reported also by Hepp-Kuschel (1989). Thus the higher intake is partly a consequence of greater herbage mass. He suggested that the herbage mass located in the upper layers (over 2 cm) would influenced the sensitivity of grazing lambs to sward height or herbage mass changes. Furthermore, the lambs were older and heavier in Period 6 than in Period 5 and therefore this may also have influenced intake.

Lambs' performance appeared also to be sensitive to sward height treatment and was closely related to herbage intake (see Equation 4.13): lambs grazing on the 4-8 cm sward height treatment had the highest live weight gains of the three sward height treatments. On continuously grazed sown swards ranging from 3 to 9 cm sward heights, Chestnutt (1990) recorded daily live weight changes in weaned lambs from -18 to +170 g/day in autumn. Then, as also seen in this experiment, there was evidence that during the second part of the grazing season, rates of gain continued to increase up to 8 cm with no indication of a maximum value reached at 6 cm as suggested by Penning (1986) with ewes. These results emphasize the significance of sward height in determining lamb performance (Chestnutt, 1990) and although lamb live weight changes were positively related to the percentage clover in the diet (see Equation 4.12) this was only significant if the variation due to sward height was also taken into account.

Finally, the variables which were significantly related to live weight gain were herbage intake, percentage of clover on the sward surface and digestibility of the diet selected (see Equation 4.14). Townsend and Radcliffe (1990) also found a significant relationships between lamb live weight gains and the clover content of the pastures. All of these results suggested that weaned lambs are very sensitive to sward conditions and adjustments to stocking densities are required to ensure optimum sward composition and structure.

4.5.4.4. Parasite burden.

The interpretation of the results of this experiment, particularly the live weight gains could be confounded if

there was differential intestinal parasite burdens across the treatments. Internal parasites are of major concern in intensively farmed goats on high producing pastures (Radcliffe and Francis, 1988) but in this study lambs grazing swards previously grazed by goats did not have important faecal egg outputs. There was only a slight infestation of *Trichostrongylus spp.* on lambs grazing plots previously grazed by sheep on the 8-8 cm and 4-8 cm sward height treatment. However these levels of infestation were not likely to have affected performance (Doxey, 1971). Therefore the regular drenching of the animals during the experiment proved to be effective.

4.5.5. Summary.

Swards grazed previously by goats compared to sheep in the early part of the season had significantly higher clover DM in the sward, and particularly in the sward surface. This allowed weaned lambs to ingest a diet of higher clover content and to have higher herbage intakes and lamb live weight gains.

Also incorporating a period of rest from grazing allowing the sward to grow from 4 cm to 8 cm over a period of 3 weeks in mid-summer, favoured white clover compared to ryegrass as it was the species with a greater capacity for growth during the rest period. Higher weaned lamb live weight gains were recorded on 8 cm swards which had been allowed to grow from 4 cm to 8 cm, compared to swards which had been maintained at 8 cm throughout the summer.

The experiment thus provides information on ways in which the clover content and structure of grass/clover

swards can be managed by the appropriate choice of animal species and grazing managements to the benefit of weaned lambs.

CHAPTER 5

GENERAL DISCUSSION

This chapter initially discusses some aspects of the techniques used in the experiments to measure sward composition, diet selection and herbage intake (Section 5.1). A section on the effect of animal species on sward composition and its interaction with sward height and season follows (Section 5.2). Finally, the implications of the major findings for sequential grazing and management of sown swards are considered (Section 5.3) and some recommendations for future research are made (Section 5.4).

5.1. Experimental techniques.

5.1.1. Measurement of sward canopy composition and structure.

A herbage gripping and stratified clipping technique was used to identify changes in the botanical components and vertical structure of the sward as explained in Sections 3.2.6.2 and 4.2.6.2. Advantages of using this technique were that it:

- gave samples of plant material for direct measurement of foliage distribution in the canopy and botanical composition of the sward.

- enabled measurements to be made in the laboratory following separation into several components, prior to drying and weighing. The technique is therefore less dependent on variations in the weather than the point quadrat technique (Rhodes and Collins, 1993).

The major disadvantage of this technique is that no simultaneous measurements could be made of spatial arrangement of the plant material within the horizontal layers of the canopy. The point quadrat method can give such information. However this can lead to more complicated statistical considerations, as the numbers of contacts and their angles are not distributed equally between layers with the result that the accuracy of contact frequency estimates are not uniform for all layers. Also with the point quadrat technique, as sward canopy height can affect the herbage mass at a given sampling height there can be a difficulty in collecting data for the lower strata of swards with very dense layers. The problem does not occur with the stratified cutting technique. A further advantage of the technique used is that it was possible to relate the dry matter percentages in the diet selected by the animals to the dry matter percentages in the sward, thus easing interpretation of the data. This is not possible with point quadrat data without the use of factors to convert frequency data to mass data, which can introduce a degree of error.

The pyramidal distribution of grass and clover components in vertical layers of the sward canopy has been reported before by several workers (Arosteguy, 1982; Milne *et al.* 1982; L'Huiller *et al.* 1986; Collins, 1989; Hughes, 1990; Nicol and Collins, 1990; Stevens *et al.*, 1992; Casey, Lucas and Stevens, 1993) and seems to be a natural consequence of the architecture of the grass tillers and clover units (Hodgson, 1990). Collins (1989) divided

swards into 4 cm horizontal layers but found that this was too large to define grazing site accurately. Therefore it was decided to use a 2 cm horizontal band width. Similarity coefficients between the composition of samples from oesophageally fistulated animals and of each horizon, as calculated by Collins (1989) and Nicol and Collins (1990) were not assessed in the present study. As Collins (1989) herself recognized, it would be difficult and even unrealistic to interpret grazing in a particular horizon as the animal's ability to choose a grazing site with a high proportion of a particular component, as botanical components present in higher proportions within a horizon would distort the measure of similarity. Also the herbage mass differences between horizons would complicate the interpretation of the results achieved. Consequently in Experiment 1 sheep and goat diets were compared only with pasture composition within the whole sward and sward surface.

Despite the wide variation in sward conditions created in the current study, complete dissociation of the most important sward variables were not apparently achieved in Experiment 1. As explained in Section 3.5.4.1 some attributes of the grazed strata which are important in determining diet selection were not described adequately in the procedure used to determine the sward surface composition. Selection of clover by sheep and goats was not entirely explained by the sward variables used in Equations 3.2 and 3.3, with substantial additional variation in diet selection accounted for the pre-species treatments in Phase 1. The depth at which animals position their mouths when biting is largely determined by sward height (Laca *et al.*, 1992a) and hence a better understanding of the mechanisms behind spatial structure of the sward components requires knowledge of the determinants of choice of grazing location and intensity of utilization

by grazers as measured by bite depth, bite area, bite volume, grazed stratum bulk density, etc. (Milne, 1991; Laca *et al.*, 1994a). For instance, the concept of a sward surface stratum may help to explain the mechanisms of vertical selection by sheep and goats but does not consider selection for clover in the horizontal plane (i.e. patch selection).

However, the close relationships between percentage of clover present on the sward surface and lamb responses during Phase 2 in Experiment 2 provided confidence that the procedure used to describe the sward surface gave results that reflected to some extent the state of the sward as perceived by the grazer. However sward height was the most important variable in explaining the percentage clover consumed by lambs because of the correlation between sward height and clover content of the whole sward and sward surface.

5.1.2. Measurement of diet selection.

Oesophageally fistulated animals are used extensively in grazing experiments with domestic animals, although they are not extensively yet used in wild herbivores, in the measurement of diet selection, herbage intake and bite size (McManus, 1981). Gordon (1994) points out the constraints of this technique on the basis of (i) requirement for surgery (ii) possible biases because of the short time of period for collection of samples and the relatively small area sampled and (iii) that grazing behaviour of fistulated animals may differ from that of intact animals (Coates, Schaechenmann and Jones, 1987; Jones and Lascano, 1992). However, comparisons by several authors (Forbes, 1982; Forbes and Beatty, 1987) showed that there was no reason to

suspect any major differences in grazing mechanics between fistulated and non-fistulated animals. In using fistulated animals, it is crucial to get animals thoroughly trained and accustomed to experimental procedures, otherwise the results may be biased (Hall and Hamilton, 1975; Vogel, Moore and Johnson, 1991). In both experiments the fistulated animals had a similar management history, nutritional background and body condition to the non-fistulated animals and there was no reason to suppose that the ingestive behaviour of the fistulated and non-fistulated animals differed. Therefore, oesophageally fistulated animals still provide the most useful technique to determine the botanical and chemical composition and digestibility of the diet selected by grazing animals.

5.1.3. Measurement of the herbage intake.

Mayes *et al.* (1986) suggested n-alkanes present in plant cuticular wax as having potential as internal marker for estimating herbage intake. In herbage the n-alkanes with 25 to 35 carbon atoms (C_{25} - C_{35}) have predominantly an odd number of carbon atoms, while those with an even number of carbon atoms are present only in small quantities. This allows the possibility of making accurate estimates of the recoveries of odd-chain length alkanes in each animal by dosing with exogenous even-chain length alkanes (Mayes *et al.*, 1986; Dove and Mayes, 1991). A known amount of an even chained n-alkanes (e.g. C_{32}) is dosed to the animal, for example in an impregnated paper pellet (Mayes *et al*, 1986; Dove and Mayes, 1991). Feed intake prediction depends on equal recoveries of the dosed alkane (C_{32}) and its naturally occurring odd-chain alkane (e.g. C_{33}). Mayes *et al.* (1986) tested the basic methodology of the technique in sheep fed with cut herbage in an indoor trial and the

C_{32}/C_{33} alkane pair gave remarkably good estimates of herbage intake. C_{34} alkane is added as an internal standard to the freeze-dried samples collected. Samples are saponificated and extracted through silica gel columns to leave alkanes in the eluate. Finally, the n-alkanes in the hydrocarbon fraction are analysed by gas-liquid chromatography.

The advantages of this technique are that assuming similar recoveries for odd and even-chain alkanes of similar chain length, administration of known quantities of even-chain alkanes allows calculation of herbage alkane recovery and allows accurate intake estimation without the need for faecal output determination. Estimates of herbage intake in grazing animals have traditionally been made from measurements of faecal output and digestibility. Faecal output has been measured directly by total collection (Langlands, 1975) or by the dilution of a dosed indigestible marker such as chromic oxide (Parker, Morris, Garrick, Vincent and McCutcheon, 1990). The n-alkanes does not require an independent determination of the digestibility of the diet consumed, nor does it rely on the quantitative recovery of a dosed marker. Also biases in the estimates of herbage, faecal and dosed n-alkanes concentration would lead to proportional biases in the estimate of intake but would have no effect on precision (Vulich, O'Riordan and Hanrahan, 1991). A representative sample of the herbage consumed is still required, however, to allow measurement of the n-alkane concentration and this still represents a major limitation.

Other potential problems may arise as the technique requires:

- to have the naturally occurring n-alkane (usually C_{33}) in sufficient concentration in all the forage species

present in the pasture.

- no diurnal variation in faecal alkane concentration or that the dosed and natural alkane concentration in the faeces vary diurnally in a similar manner. Mayes *et al.* (1986) failed to show any cyclical pattern of changes in the odd:even chain alkane ratio through the day. If that occurred, the practical solution for intake estimation in the field might involve twice daily dosing or a form of pellet from which the alkanes were less readily released.

- to have the same faecal recoveries of both the dosed and natural n-alkanes used in the estimation of intake.

- a 5-6 day period of dosing alkanes to allow the faecal concentration of dosed alkane to reach equilibrium as reported by Mayes *et al.* (1986).

- a relatively slow dispersion of dosed alkanes as Dove and Mayes (1991) saw that dosed alkanes are likely to be more available for microbial attack and show less complete recovery than herbage alkanes. This is due to the fact that dosed alkanes follow the liquid phase in the digestive tract while herbage alkanes tend to be associated with the solid phase.

- freeze-drying during the sample preparation instead of oven-drying. There is evidence that the direct saponification procedure does not always eliminate the loss of alkanes associated with oven-drying (Lamb and Mayes, unpublished data). In this respect, Dove and Mayes (1991) suggested further research on the effects of different drying temperatures and their interaction with sample type.

Care must also be taken in the laboratory analysis to identify any contamination, fractionation or extraction

problems (Mayes, personal communication). He recommends duplication of extractions, the running of quality control samples through complete analysis to allow contrasting results when appropriate, to aim for well-separated 'good' shaped peaks on the resulting gas-liquid chromatogram and to run gas-liquid chromatographic analysis under isothermal conditions to eliminate problems associated with temperature (Mayes, personal observation).

Dove and Mayes (1991) and Mayes (personal communication) suggests further applications of this technique in the measurement of a)- diet composition in ruminants, b)- intake and diet composition in monogastric herbivores such as pigs and horses and in wild hervibores, c)- digesta flow rates and rate of passage.

5.2. Effects of animal species on sward composition.

Swards are characterised not only by vertical distribution of the preferred components but also by their horizontal distribution (Milne, 1991) and as seen in Experiment 1 there were differences on sward composition between areas differing on mean sward surface heights across animal species treatments and that affected the proportion of clover consumed by sheep and goats. Cattle-grazed swards resulted on higher clover contents than sheep- and goat- grazed swards and this was mainly related with higher proportion of clover on the short and tall sward areas and particularly with higher clover masses on the tall sward areas. It seemed likely that the greater patchiness developed under cattle grazing allow clover to be laxly grazed in the more rejected areas (taller areas).

Laca *et al.* (1994a) pointed out that no single

relationship between average foraging strategy behaviour and average pasture characteristics can be expected, unless the pastures are completely homogeneous or their heterogeneity is controlled across changes in availability. Therefore, treatment of different sward areas as patches within the sward could be an useful approach to interpreting and predict more accurately the possible effects of the distribution of clover on the grazing behaviour of the animals.

Goat-grazed swards had higher clover contents than sheep-grazed swards in Experiment 2 and in Phase 2 of Experiment 1. But this did not occur in Phase 1 of Experiment 1. This may have been due to seasonal variations and sward height effects on the availability of clover in the sward to the grazer. During Phase 1 of the Experiment 1, clover may have not occupied a higher position in the sward canopy because its growth may have been limited by non-favourable environmental conditions since temperatures were lower than average. This highlights the potential importance of interaction between animal species, sward conditions such as height and environmental factors.

5.3. Implications for management.

Most experiments on mixed grazing have been conducted with no consideration given to sward conditions and it is not possible to predict whether any benefit would be gained under a different set of circumstances (Nolan *et al.*, 1993). A fixed sward state allowed more efficient control of the material harvested as a proportion of that grown rather than using a traditional stocking rate approach (Nolan and Connolly, 1977).

With single animal species grazing, the optimum sward height tends to be a compromise between maximising individual animal intake in terms of quantity and avoiding a decline in nutritive value due to flowering of grass tillers. In the current study, the between-sward height treatment differences in grazing pressure produced different changes in sward structure and this may affect the balance of grass/clover in the sward. Furthermore, the availability of pasture as influenced by sward height was one of the main determinants of the different animal performances achieved in Experiment 2.

Information on the effects of sward height under sheep grazing is limited to a small range of heights. Several authors (Bircham and Hodgson, 1983; Grant *et al.*, 1983; Clarke and Harris, 1985; Parker and McCutcheon, 1992) reported increases in the variability of sward surface heights on sheep-grazed swards with a mean sward surface height above 6 cm associated with increment flower-stem. Maxwell and Treacher (1987) recommended a sward height of 6 cm under continuous sheep grazing which maximize pasture use.

Cattle, on the other hand, were seen by Wright and Whyte (1989) to have lower live weight gains at swards in excess of 8 cm. This was related to a decrease in digestibility of the herbage and an increasingly 'patchy' appearance of the sward. They recommended a sward height of 6-8 cm to be achieved as soon as possible in spring and maintained at no more than 8 cm until midsummer to avoid seed head development. Cattle-grazed swards at 6 cm in Experiment 1 maintained a leafy sward with high clover contents during the grazing season.

This work also helps in identifying how best to integrate goats into grazing systems on sown swards. With

goats there is currently little information on the mechanics of their feed intake but the intake of female and yearling castrated male goats appeared to increase linearly with sward height from 3 to 11 cm (Bown *et al.*, 1989) while Merchant and Riach (1994) suggested a sward height of 6 cm to be a reasonable minimum for goat production. As goats are shallower grazers than sheep and cattle (Gong *et al.*, 1993), they are more sensitive to changing sward height (Collins, 1989).

There is little information available on the interaction between animal species (sheep, cattle and goats) and sward height and, as seen above, since the functional response differs between animal species, an interaction is likely to occur. Thus, as the current study suggested, it may be possible to bring about advantageous changes in sward structure and productivity to benefit a particular animal species or class of livestock across different sward heights at particular times of year. Prior grazing by cattle or goats may benefit subsequent lamb performance because of increased clover content of the sward.

In summer, when mean temperatures are above 12 °C, clover has a competitive advantage over grass as seen by Marriott and Grant (1990) and allowing the swards grazed either by cattle or goats to have a period of release from grazing where swards could reach a higher sward height of 8 cm would be advantageous, as seen in Experiment 2, to earlier finishing of lambs.

Finally, the concept of sequential grazing of several ruminant species may offer opportunity to reduce dependence on pharmaceutical products for parasite control. Since cattle are susceptible to different internal parasites that sheep and goats the implications of mixing these animal

species on parasite burden needs to be considered (Blood, Henderson and Radostits, 1979). It could aid considerably in reducing cross transmitted infection of parasitism and cattle grazing may possibly 'clean' pasture in a lamb production system (Thomson and Power, 1991).

5.4. Future research directions.

This study has shown the need for improving our understanding on low input grasslands of how the distribution of clover in both the vertical and horizontal plane of the sward determines its selection by ruminants. Sampling techniques in foraging behaviour studies have traditionally not assessed the sward canopy structure. The results presented here indicated the need for further study of the influence of vertical and horizontal distribution of clover in mixed and patchy sown swards with ryegrass. This would lead to a greater understanding of the role of clover in improving the efficiency of use of low input grasslands for animal production.

Also, determining the effect of location of clover in the sward could aid the development of management strategies to encourage the persistence of clover in grass-clover swards. Furthermore, it could help in designing selection programmes to achieve clover varieties with appropriate morphological characteristics, influencing the mechanisms involved in plant competitive relationships to enable a better plant species balance in sown swards to be achieved.

Additionally, the use of grass/clover swards as a model system for measuring the potential benefits of sequential grazing by different animal species at several

sward height treatments and sward structures could help develop research of animal and sward responses to sequential grazing on a larger scale using semi-natural vegetation systems where there are wider differences in nutritive value and feeding behaviour between vegetation types.

CHAPTER 6

CONCLUSIONS

As a result of different ingestive behaviour of the different animal species used on grass/clover swards at different sward surface heights, different sward canopy structures developed and the balance in the ryegrass/white clover within the whole sward and on the sward surface was altered. In both experiments the differences in ryegrass and white clover composition were greater in the upper layers of the sward and this helped to explain the different proportion of clover selected by sheep and by goats and the differences in their performance.

In Experiment 1, the major effect of cattle grazing was to increase the clover component in pastures compared to goat and sheep grazing. Consequently, a higher proportion of clover was eaten by sheep but not necessarily by goats. Subsequent grazing by goats further increased the clover available, especially on the sward surface, when compared to subsequent grazing by sheep and this was associated with higher stock-carrying capacities.

Differences in the distribution of pasture height measurements between pre-species and species treatments in Experiment 1 and between species treatments in Experiment 2 may suggest that sheep, goat and cattle grazed at different vertical positions in the sward. In particular, sheep and goats both seemed to consume and avoided

respectively more clover from tall areas of the sward than from medium and short areas.

Although goats may avoid clover its ingestion in Experiment 1 was regulated by the canopy structure. During Experiment 2, this apparent rejection of clover produced a greater increase in clover in goat-grazed swards than in sheep grazed swards. Therefore weaned lambs had a higher proportion of clover in their diets, higher diet digestibility, higher herbage intakes and gained weight faster on pastures conditioned by goat grazing.

Sward height treatments also had an effect on animal performance. The goats', ewes' and lambs' live weight gains were found to be higher at 8 cm sward height treatment than at 4 cm height treatment and this was correlated with higher green leaf mass (grass plus clover material) present in the 8 cm sward height treatment. In the middle of summer, a later period of release from grazing, allowing the sward to grow from 4 cm to 8 cm sward height, increased the white clover content of the sward and weaned lambs which subsequentially grazed these swards had more clover in their diet and achieved higher intake and live weight gains than from swards maintained at 4 cm or at 8 cm sward height.

It can be concluded, that the appropriate choice of animal species used sequentially and managed at an optimal mean sward surface height provides a means of modifying the botanical composition and structure of grass/clover swards to benefit grass-clover balance and consequently favour subsequential lamb performance, but further research is required on the influence of vertical and horizontal distribution of plant components in swards before the diet selection and herbage intake of grazing animals can be predicted with confidence.

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APPENDIX

Appendix 1.

Botanical composition of swards in Experiment 1.

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Figure A1.5. Clover lamina-petiole vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1. 386

Figure A1.6. Clover stolon vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1. 387

Figure A1.7. Clover flower vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1. 388

Figure A1.8. Dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1. 389

Figure A1.9. Other species vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1. 390

Figure A1.10. Grass leaf vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 391

Figure A1.11. Grass pseudostem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 392

Figure A1.12. Grass flowerstem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 393

Figure A1.13. Dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 394

Figure A1.14. Clover lamina-petiole vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 395

Figure A1.15. Clover stolon vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 396

Figure A1.16. Clover flower vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 397

Figure A1.17. Dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 398

Figure A1.18. Other species vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2. 399

Figure A1.19. Grass leaf vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 400

Figure A1.20. Grass pseudostem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 401

Figure A1.21. Grass flowerstem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 402

Figure A1.22. Dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 403

Figure A1.23. Clover lamina-petiole vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 404

Figure A1.24. Clover stolon vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 405

Figure A1.25. Clover flower vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 406

Figure A1.26. Dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 407

Figure A1.27. Other species vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2. 408

Figure A2.1. The four stages in the assessment of body condition score. 411

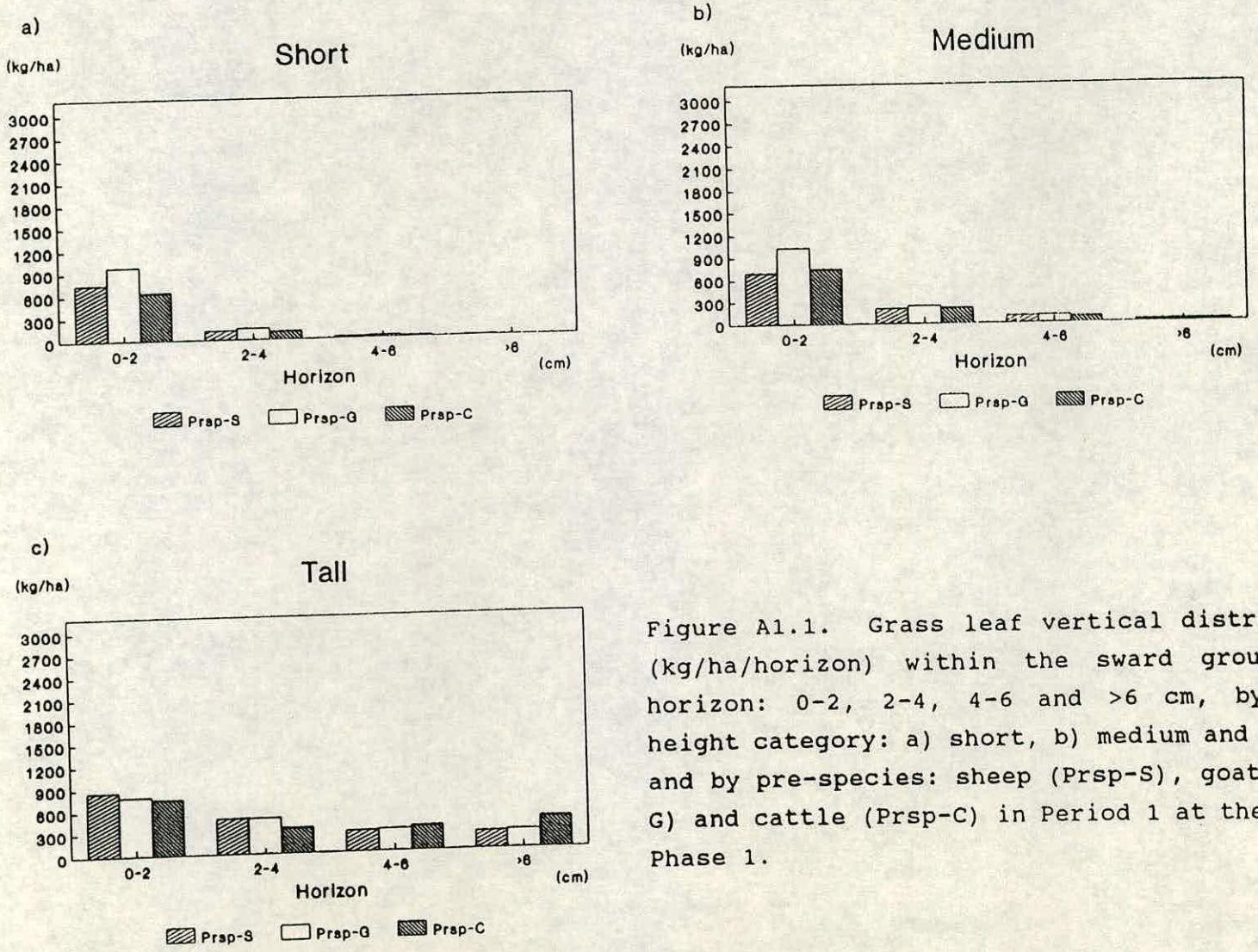


Figure A1.1. Grass leaf vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

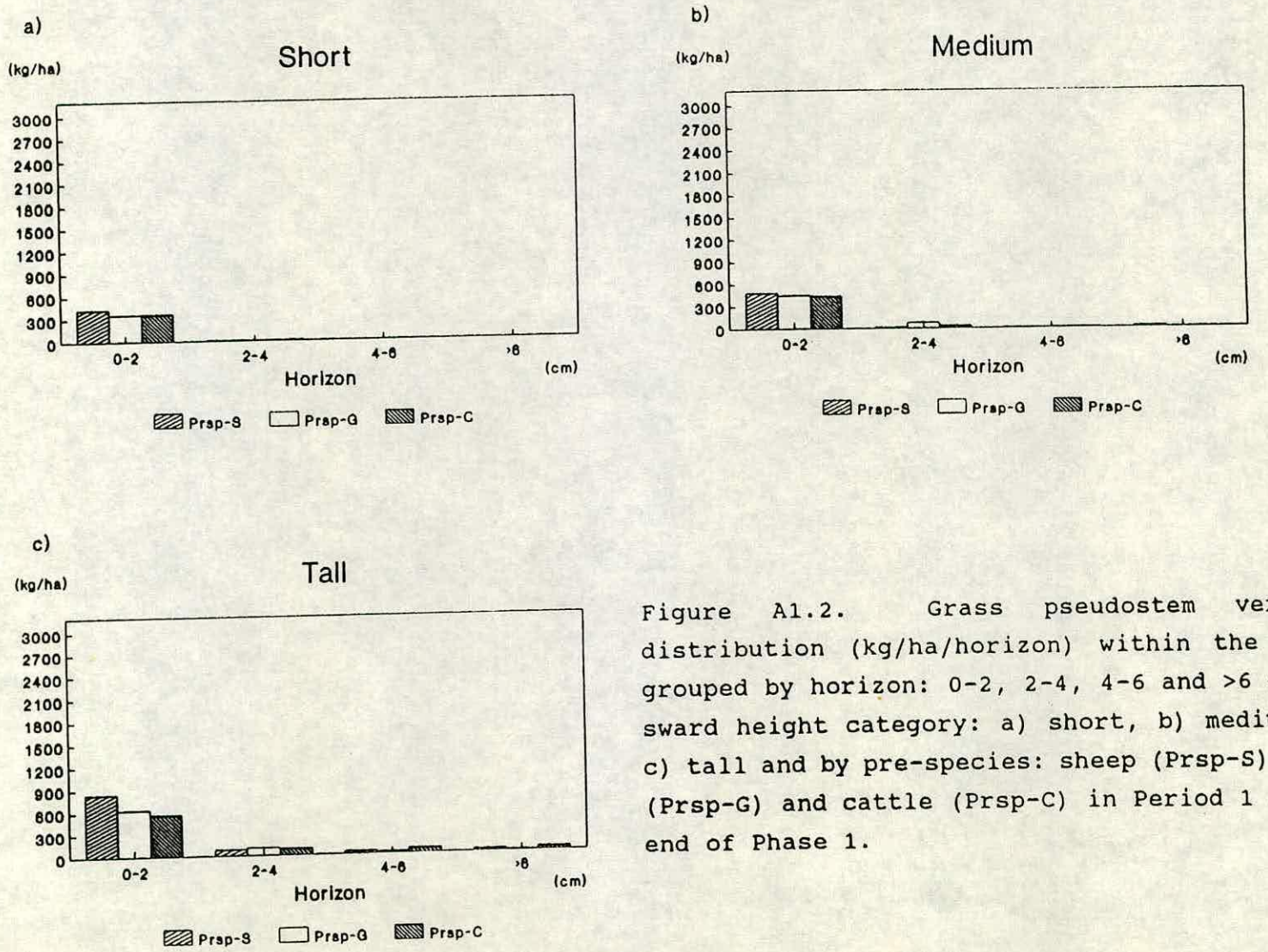


Figure A1.2. Grass pseudostem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

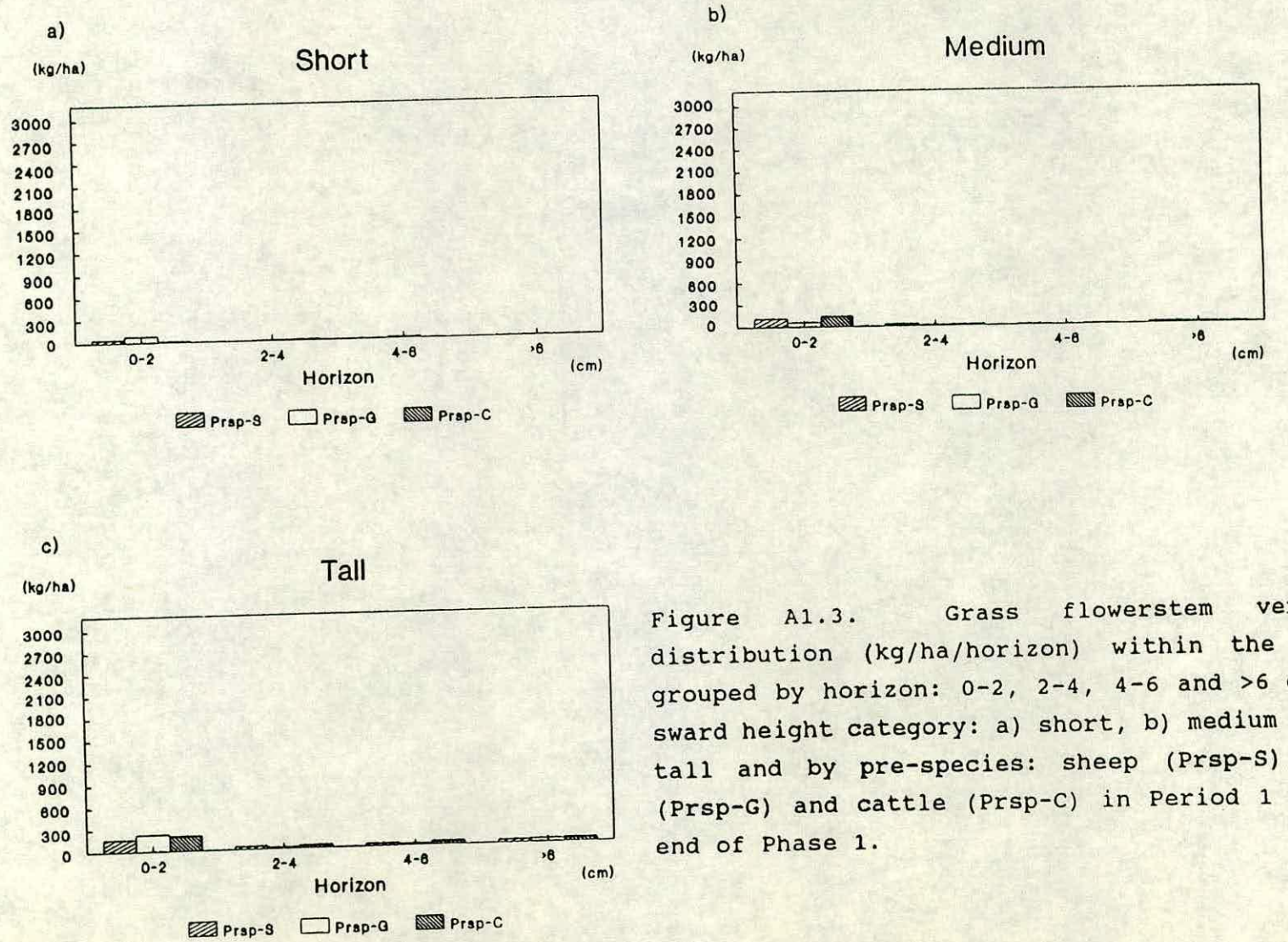


Figure A1.3. Grass flowerstem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

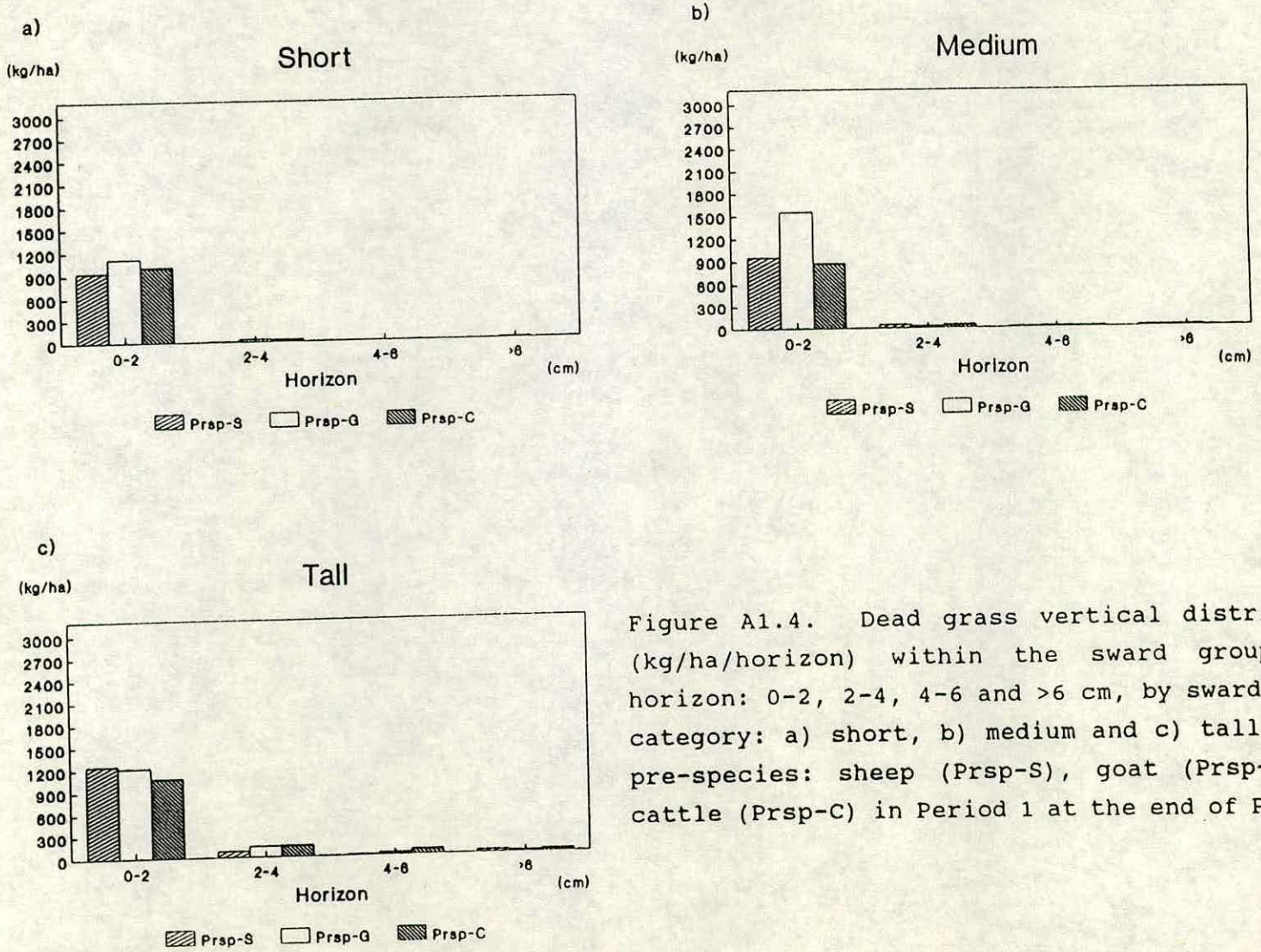


Figure A1.4. Dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

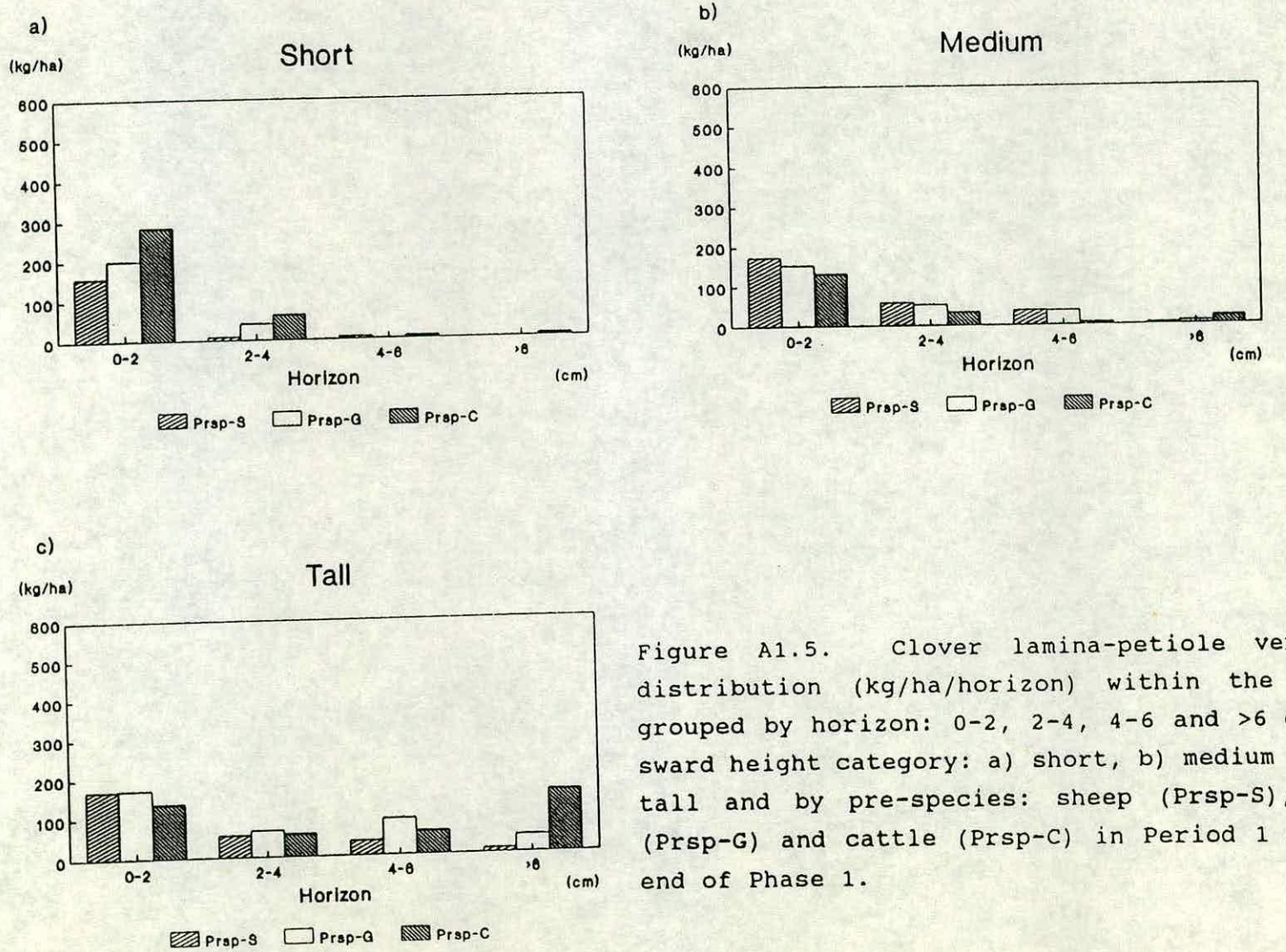


Figure A1.5. Clover lamina-petiole vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

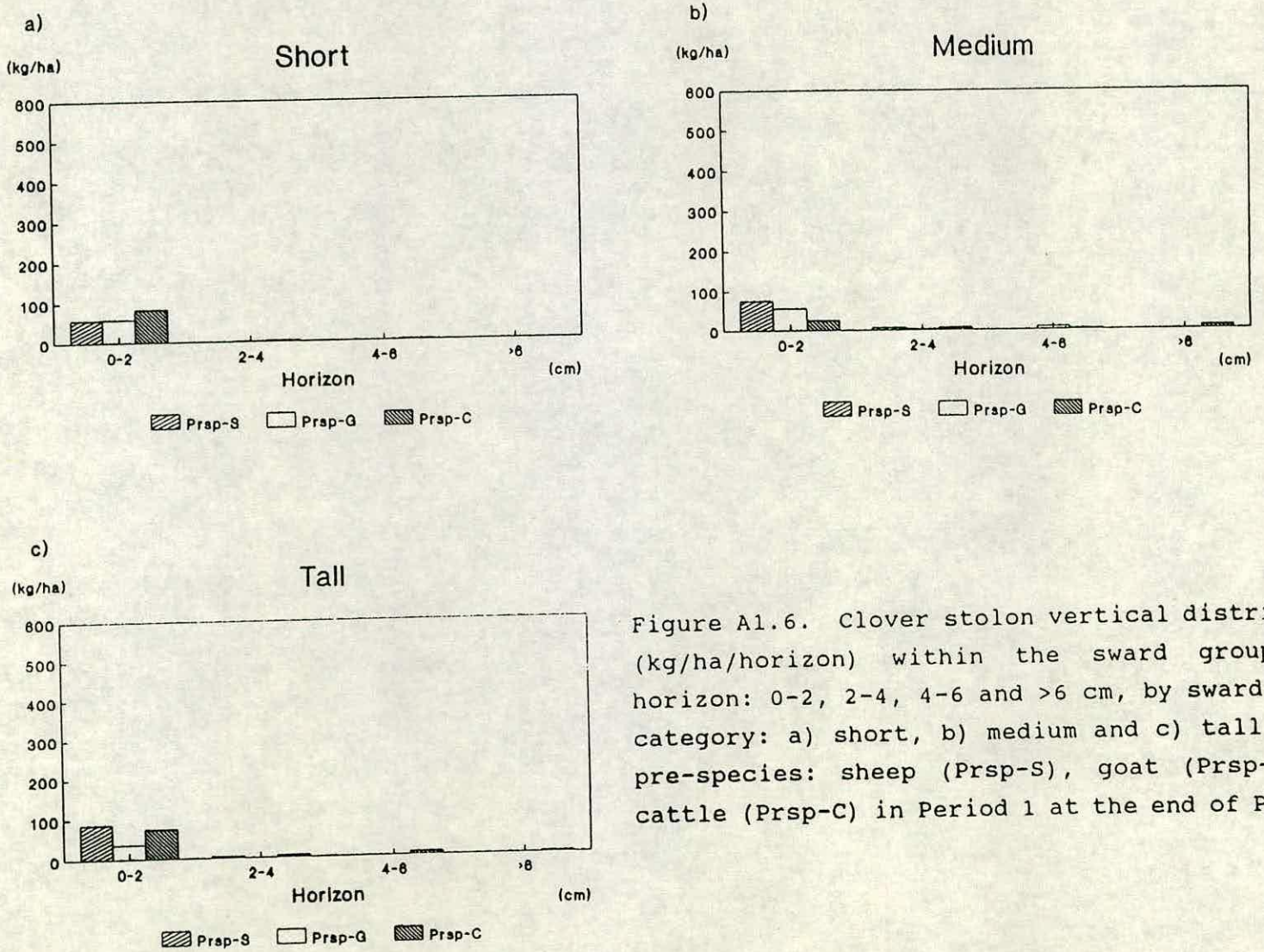


Figure A1.6. Clover stolon vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

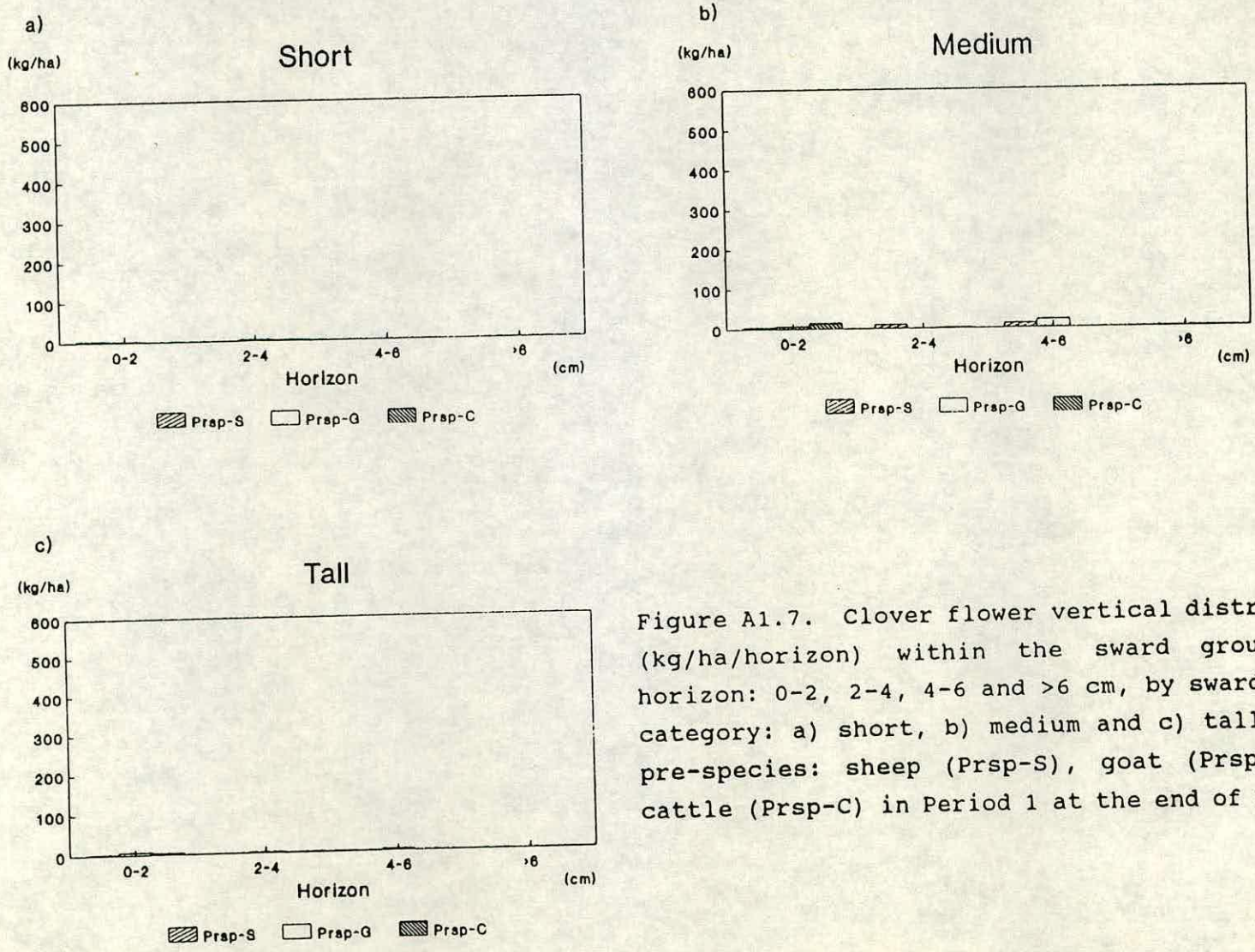
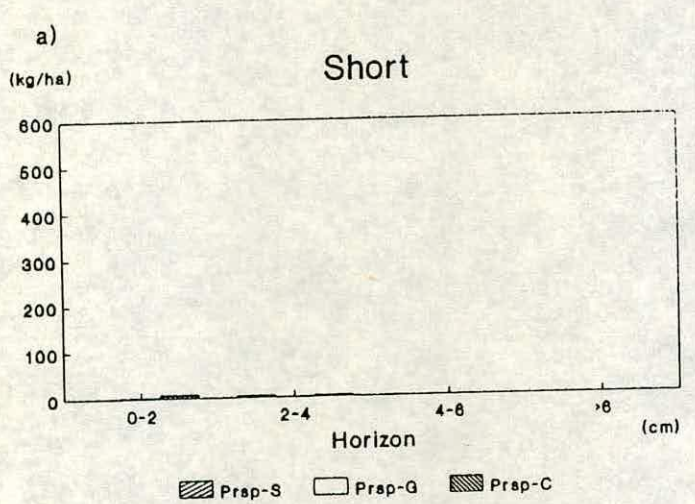
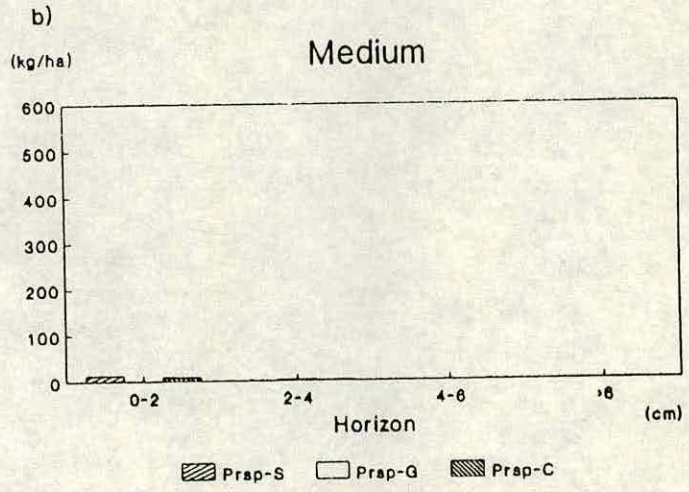


Figure A1.7. Clover flower vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.





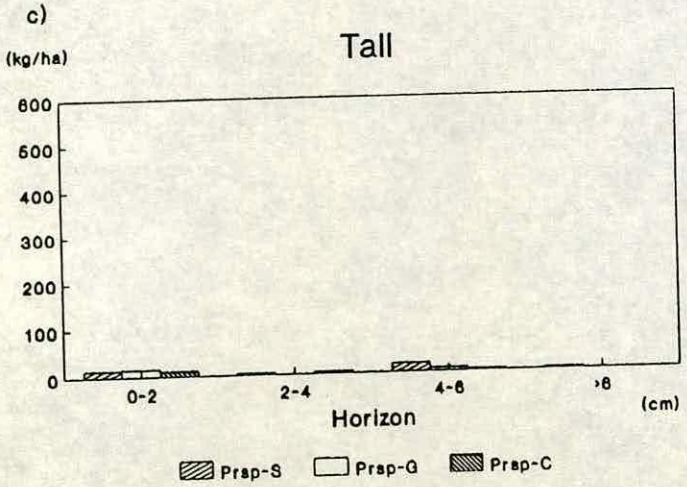


Figure A1.8. Dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

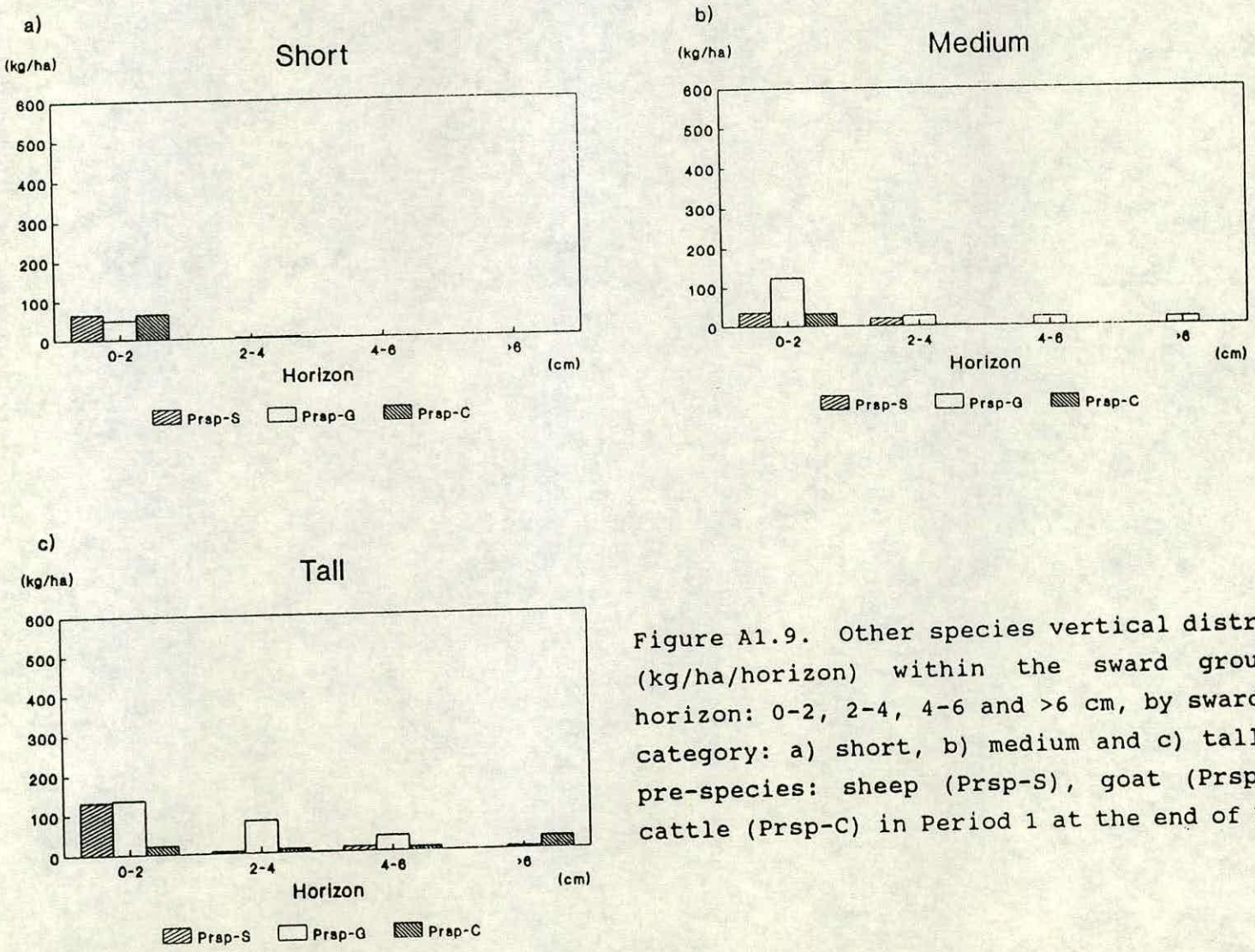


Figure A1.9. Other species vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: a) short, b) medium and c) tall and by pre-species: sheep (Prsp-S), goat (Prsp-G) and cattle (Prsp-C) in Period 1 at the end of Phase 1.

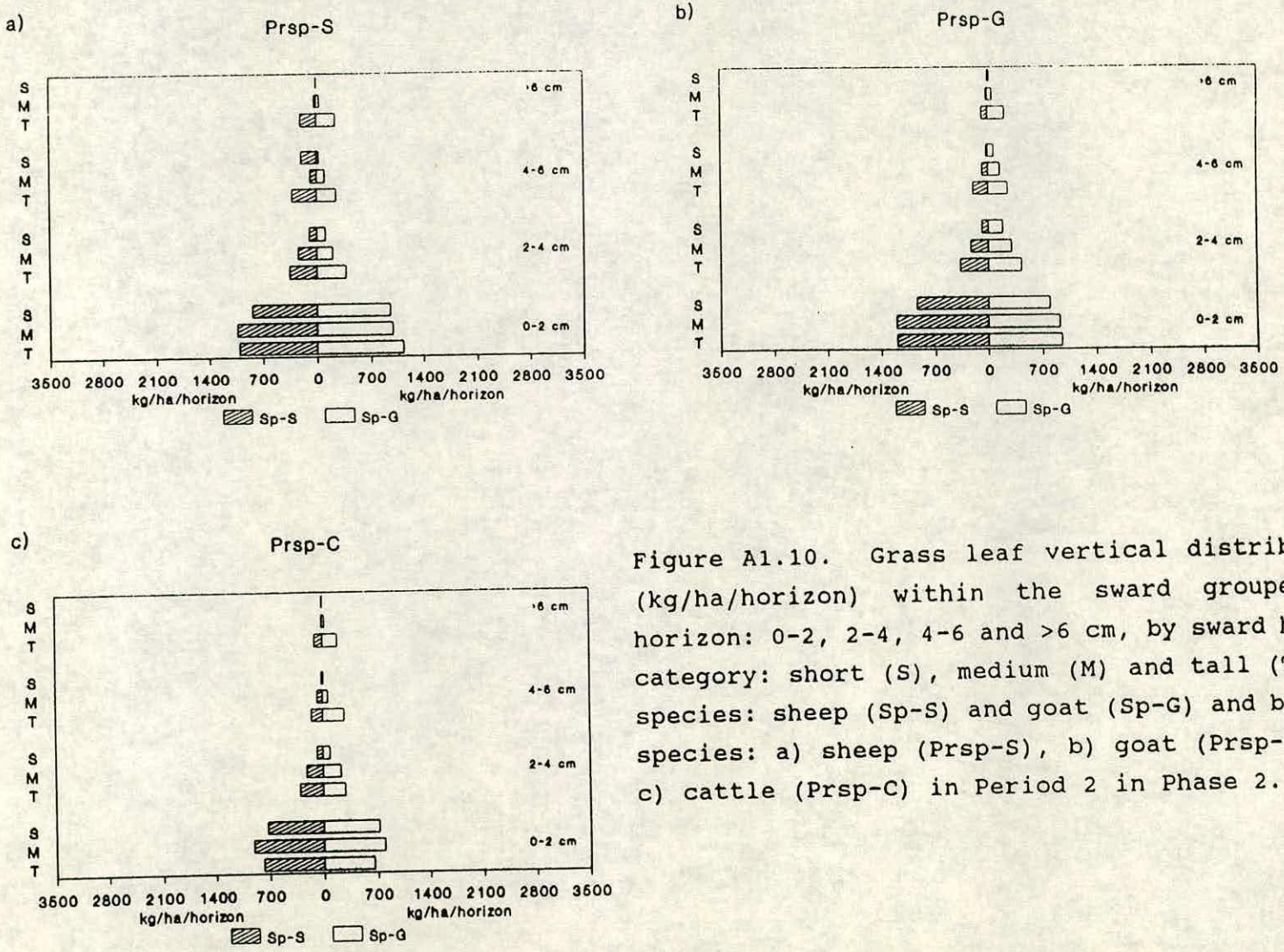


Figure A1.10. Grass leaf vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

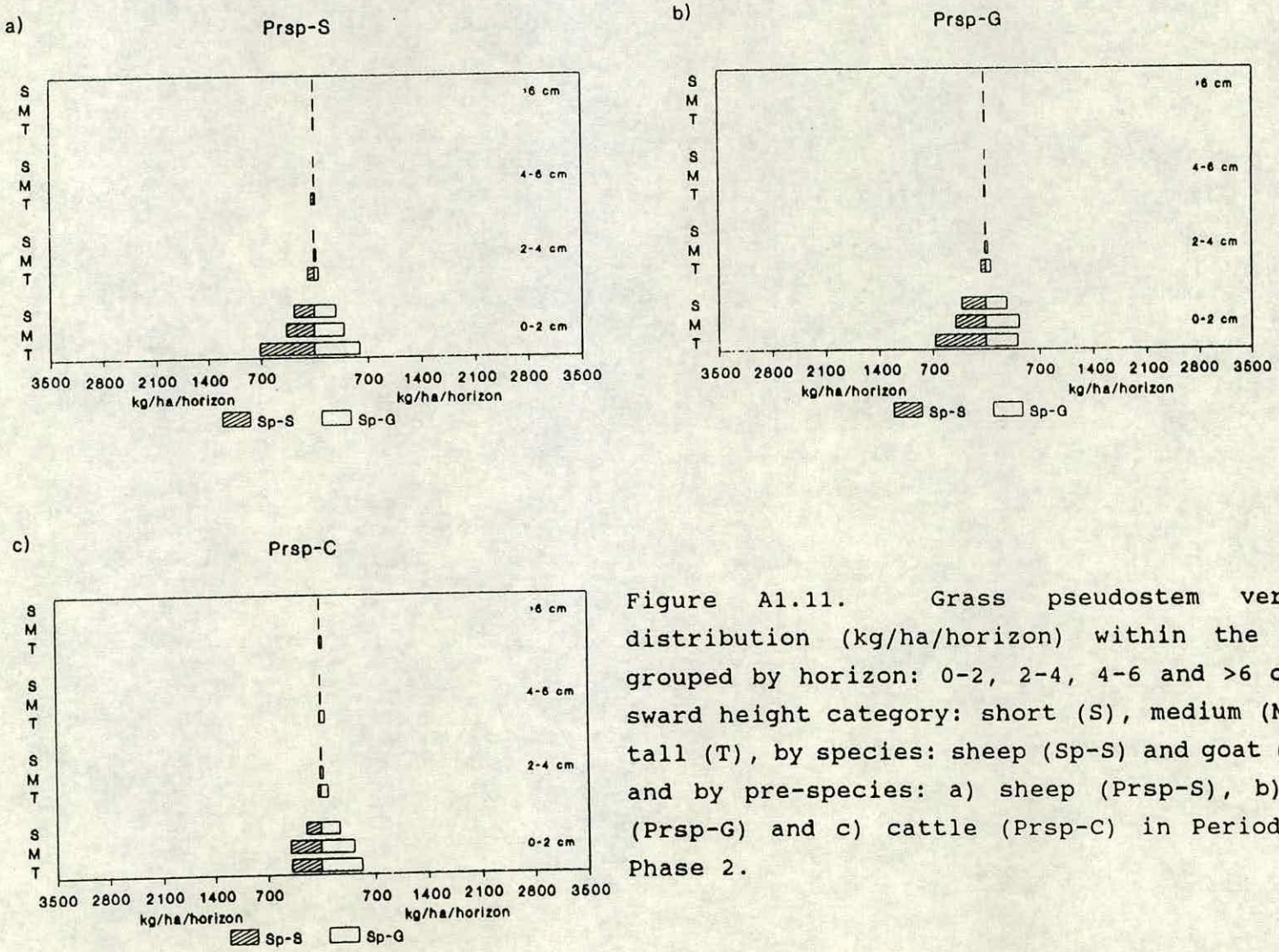


Figure A1.11. Grass pseudostem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

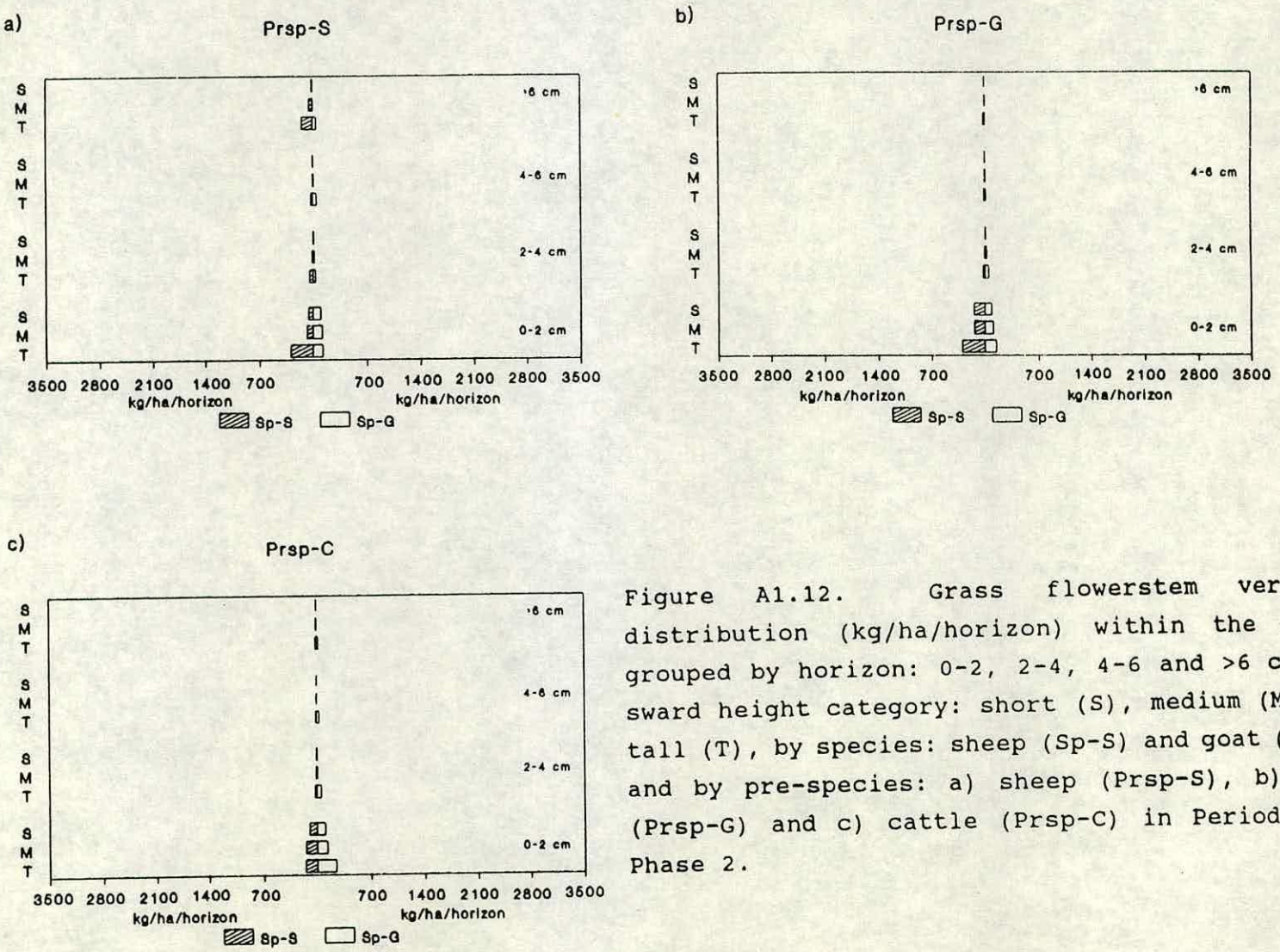


Figure A1.12. Grass flowerstem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

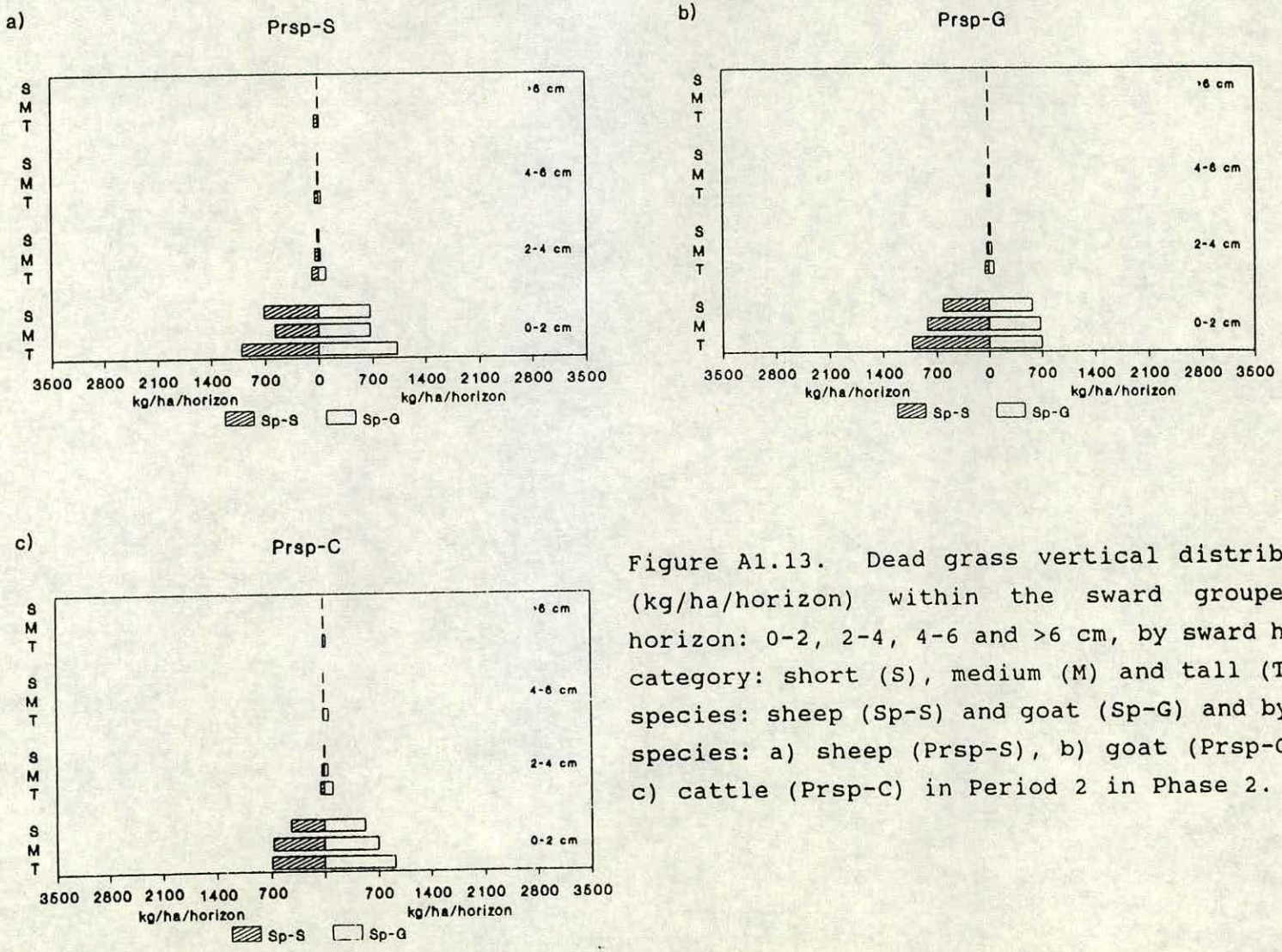


Figure A1.13. Dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

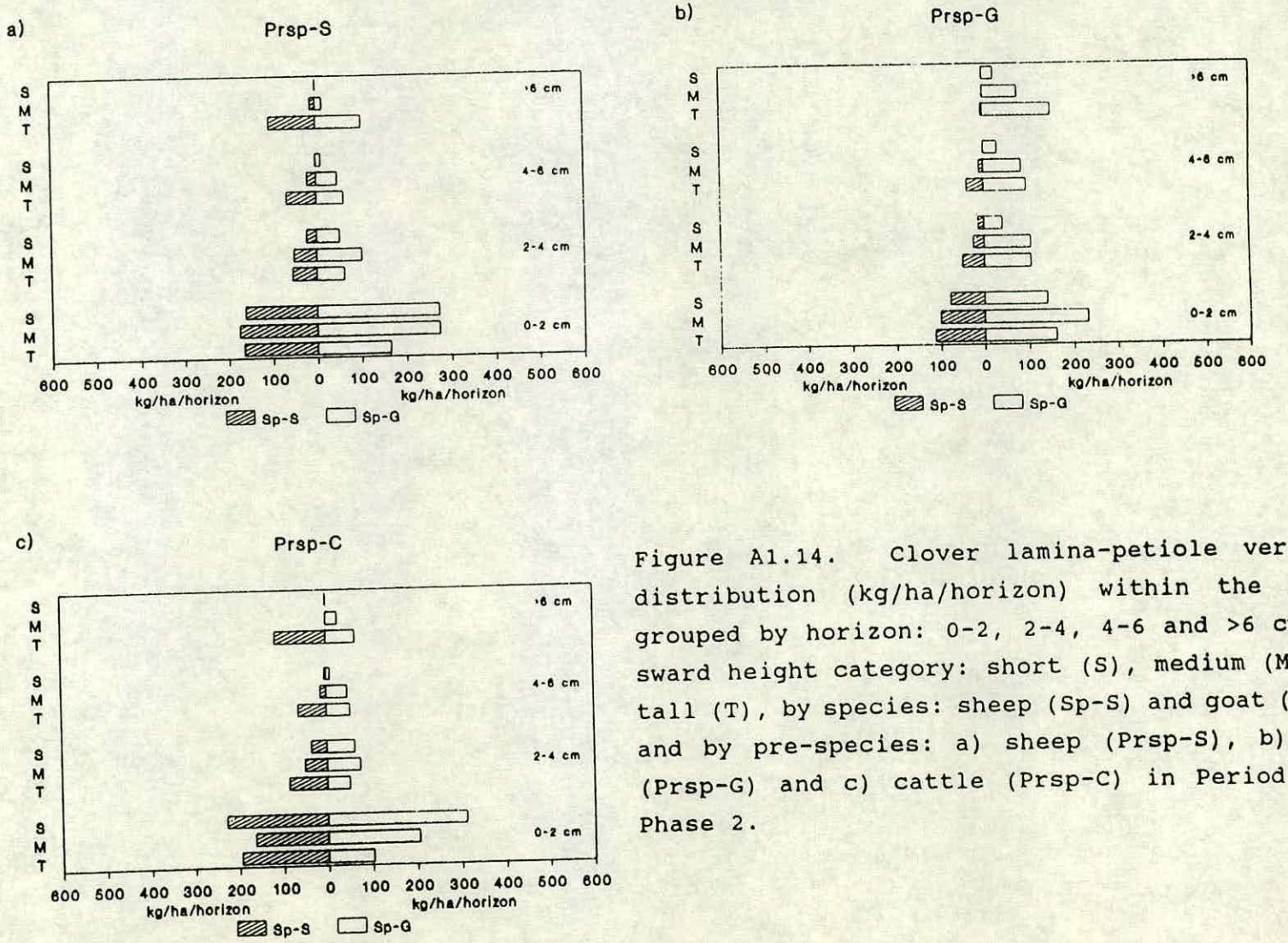


Figure A1.14. Clover lamina-petiole vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

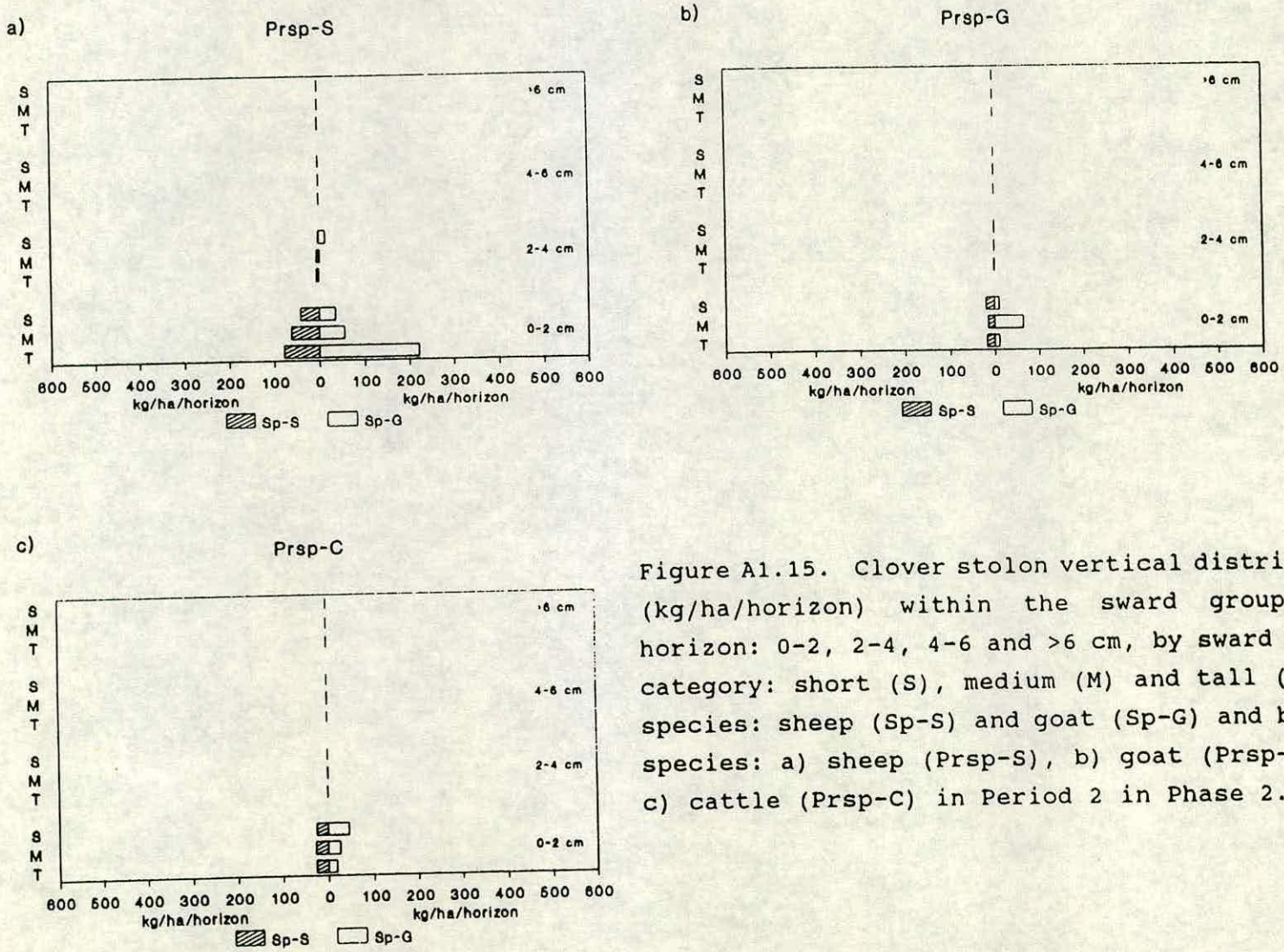


Figure A1.15. Clover stolon vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

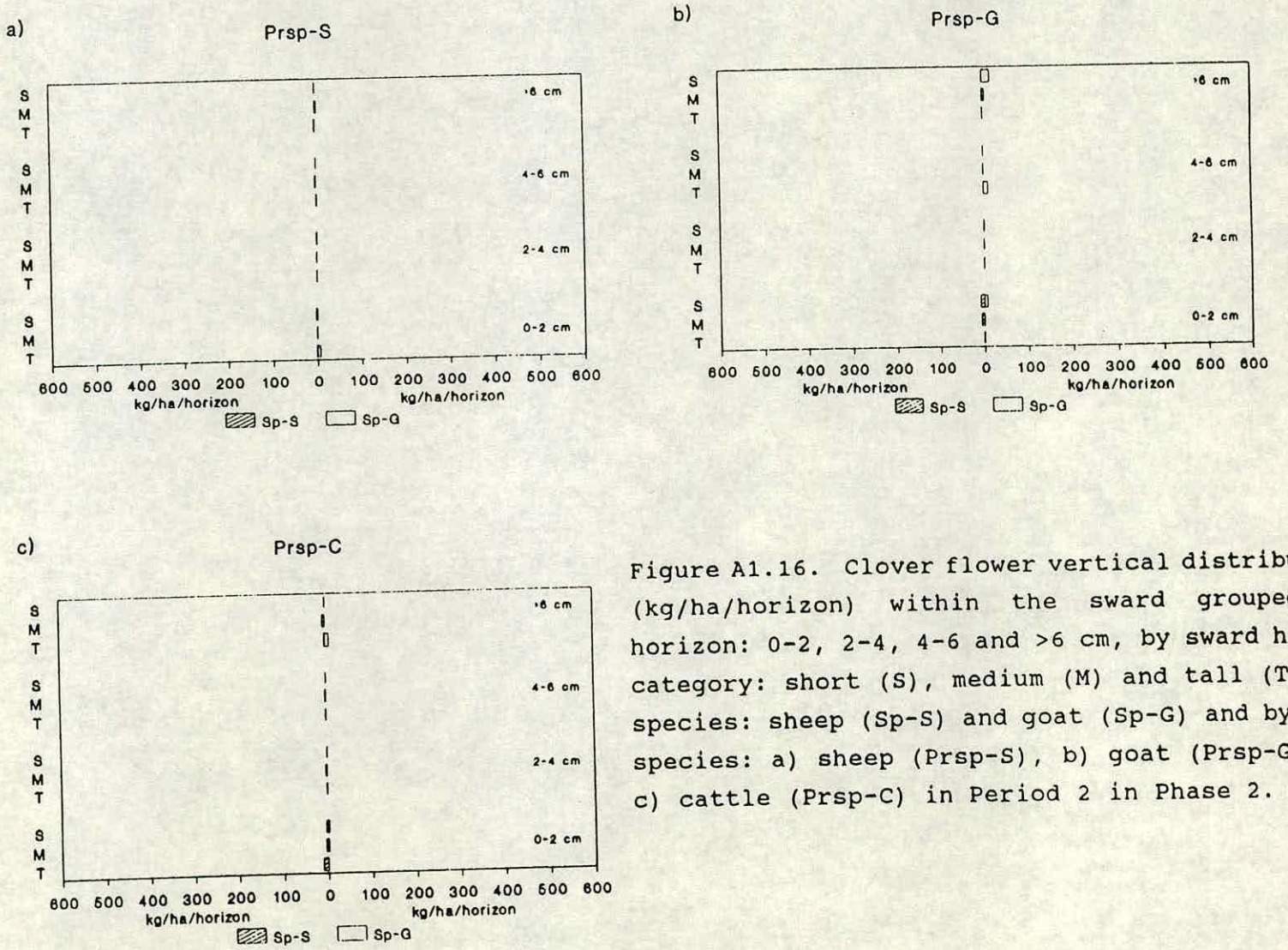


Figure A1.16. Clover flower vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

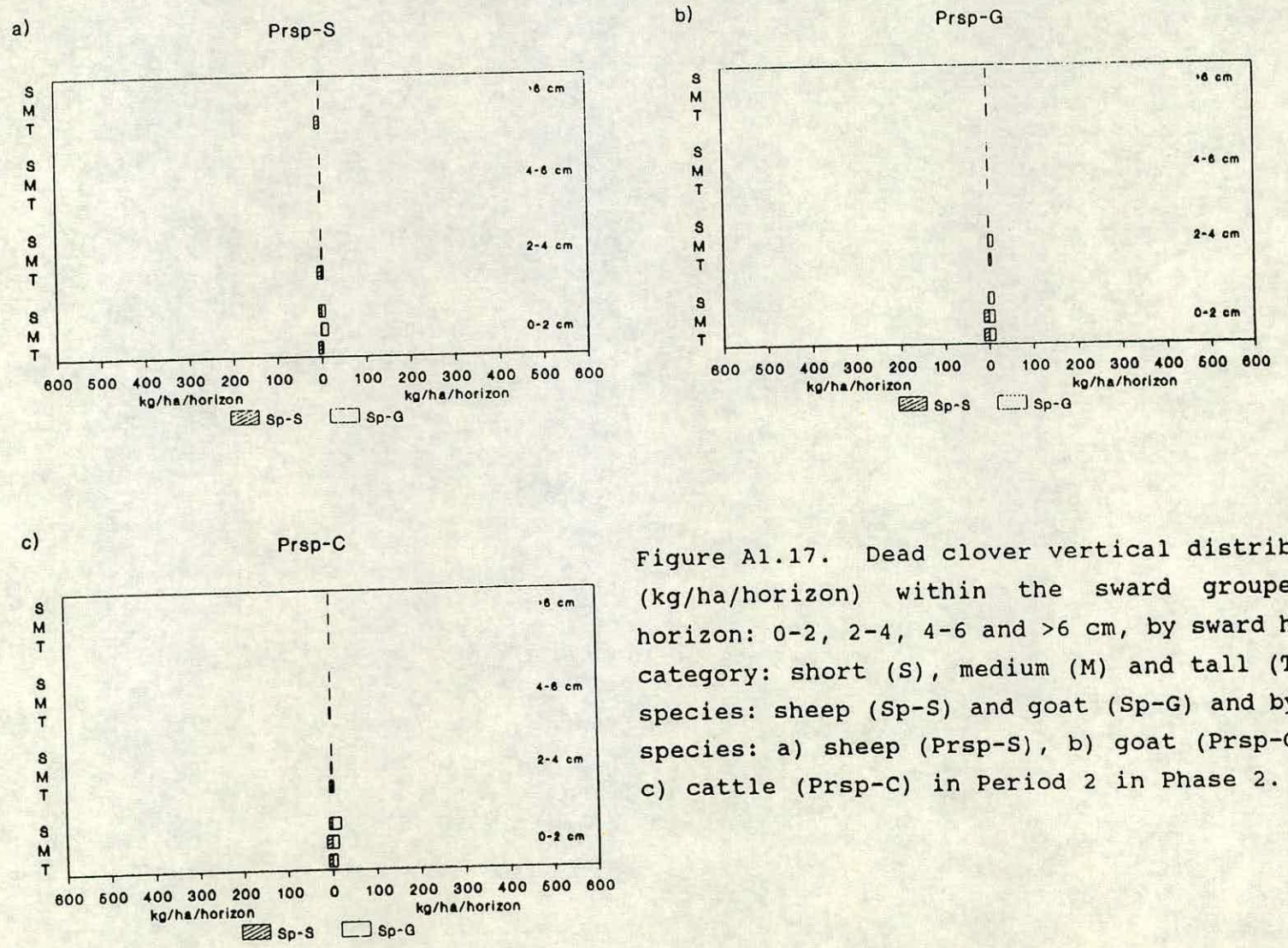


Figure A1.17. Dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

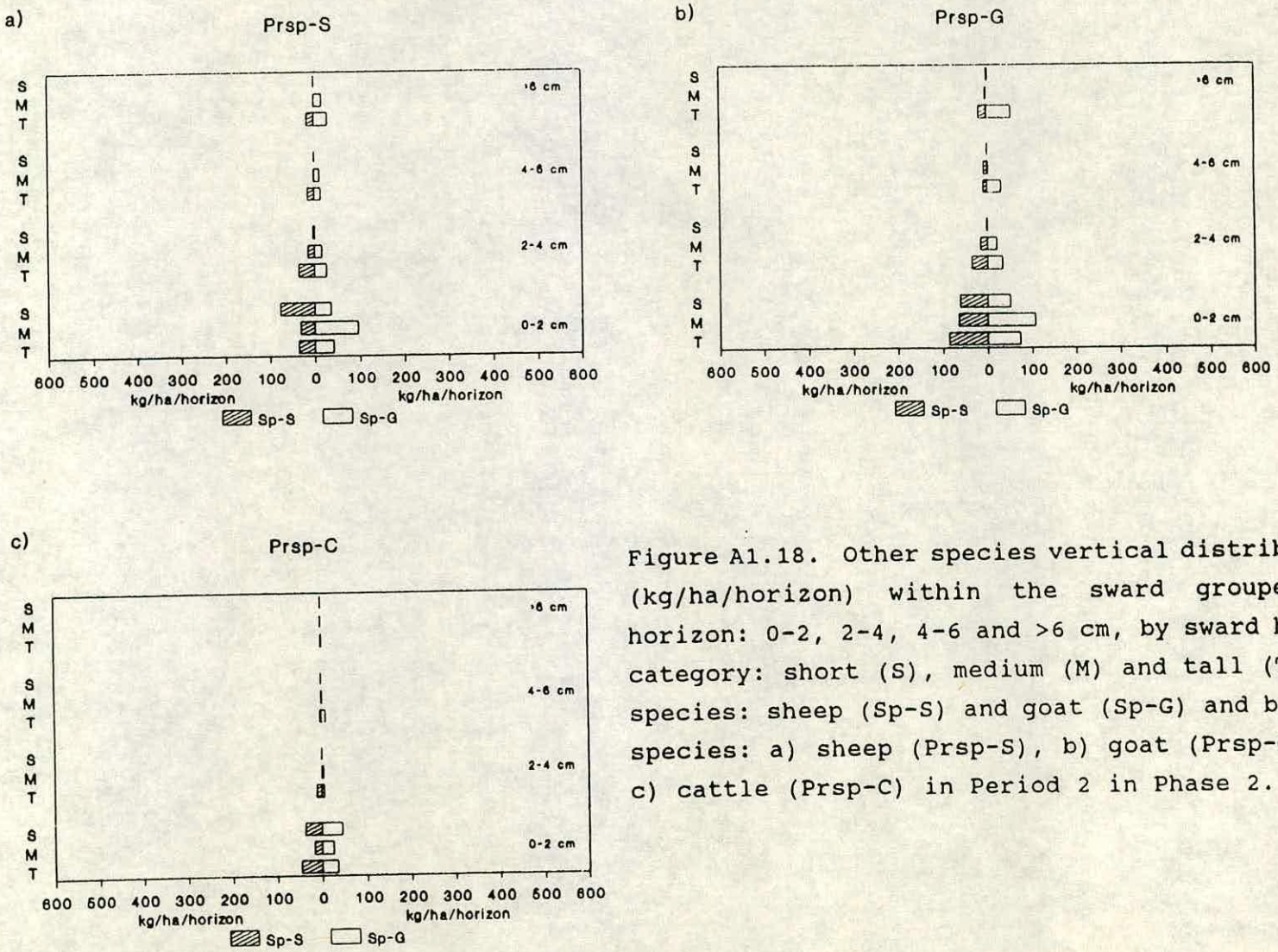


Figure A1.18. Other species vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 2 in Phase 2.

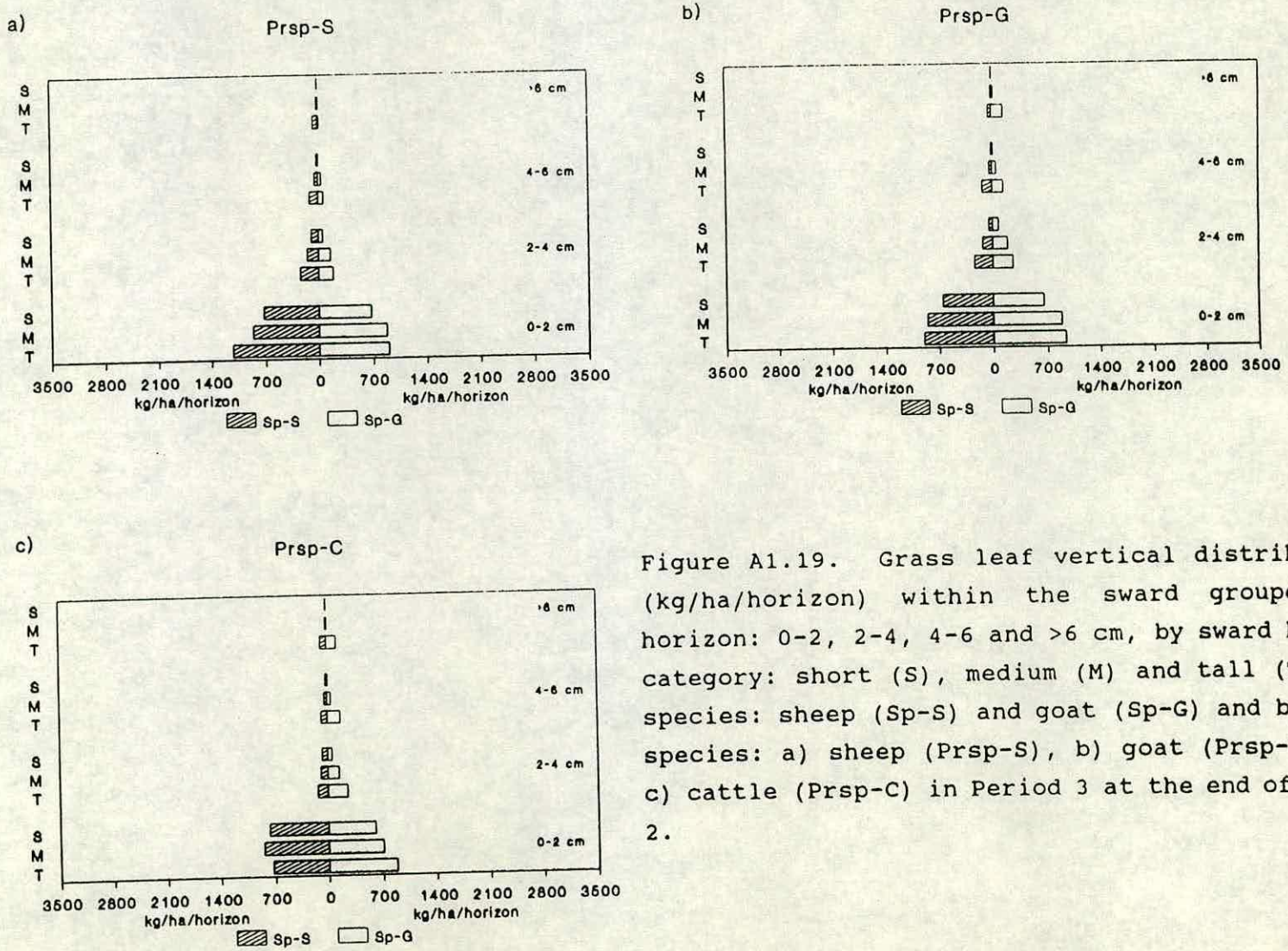


Figure A1.19. Grass leaf vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

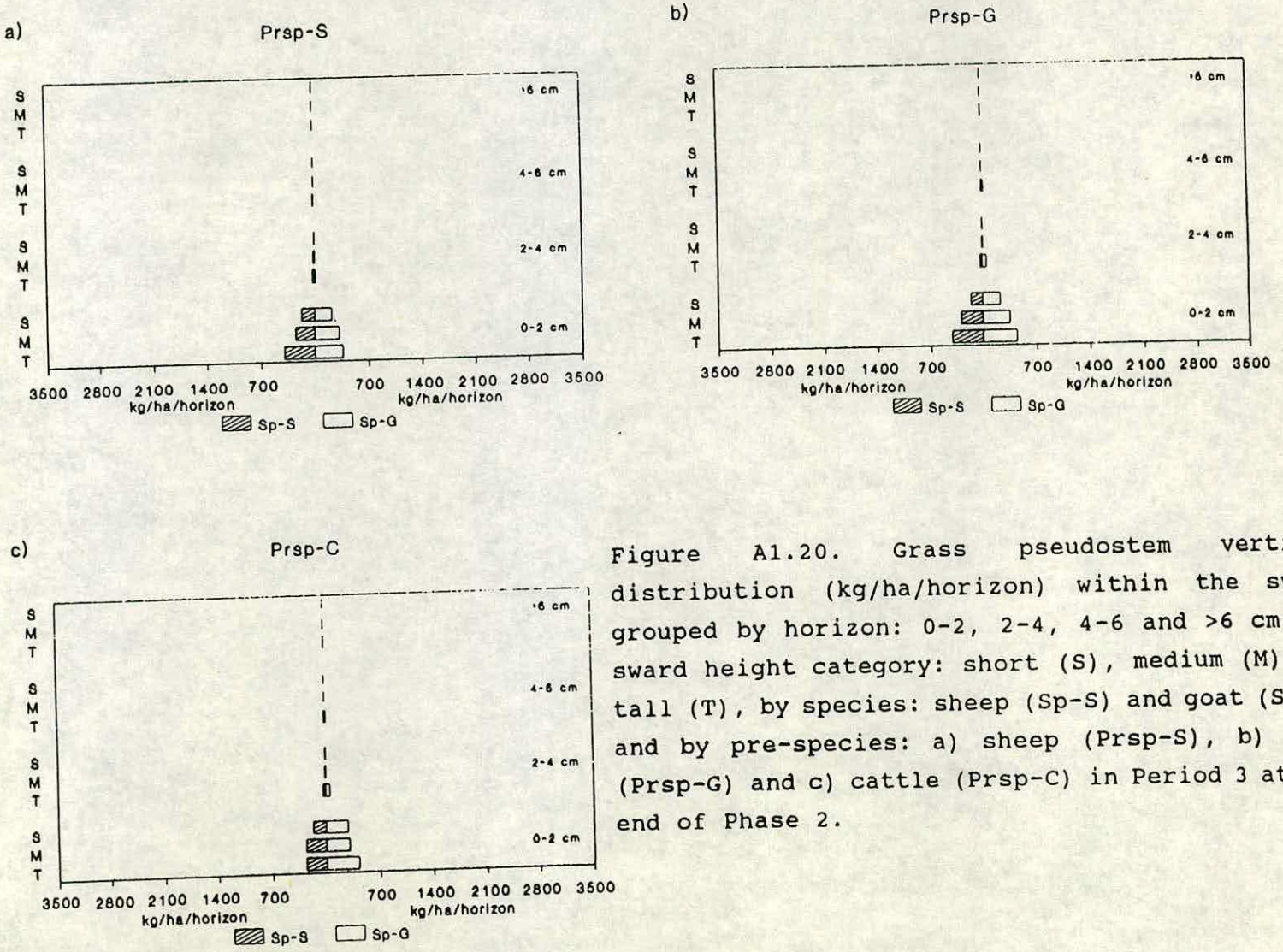


Figure A1.20. Grass pseudostem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

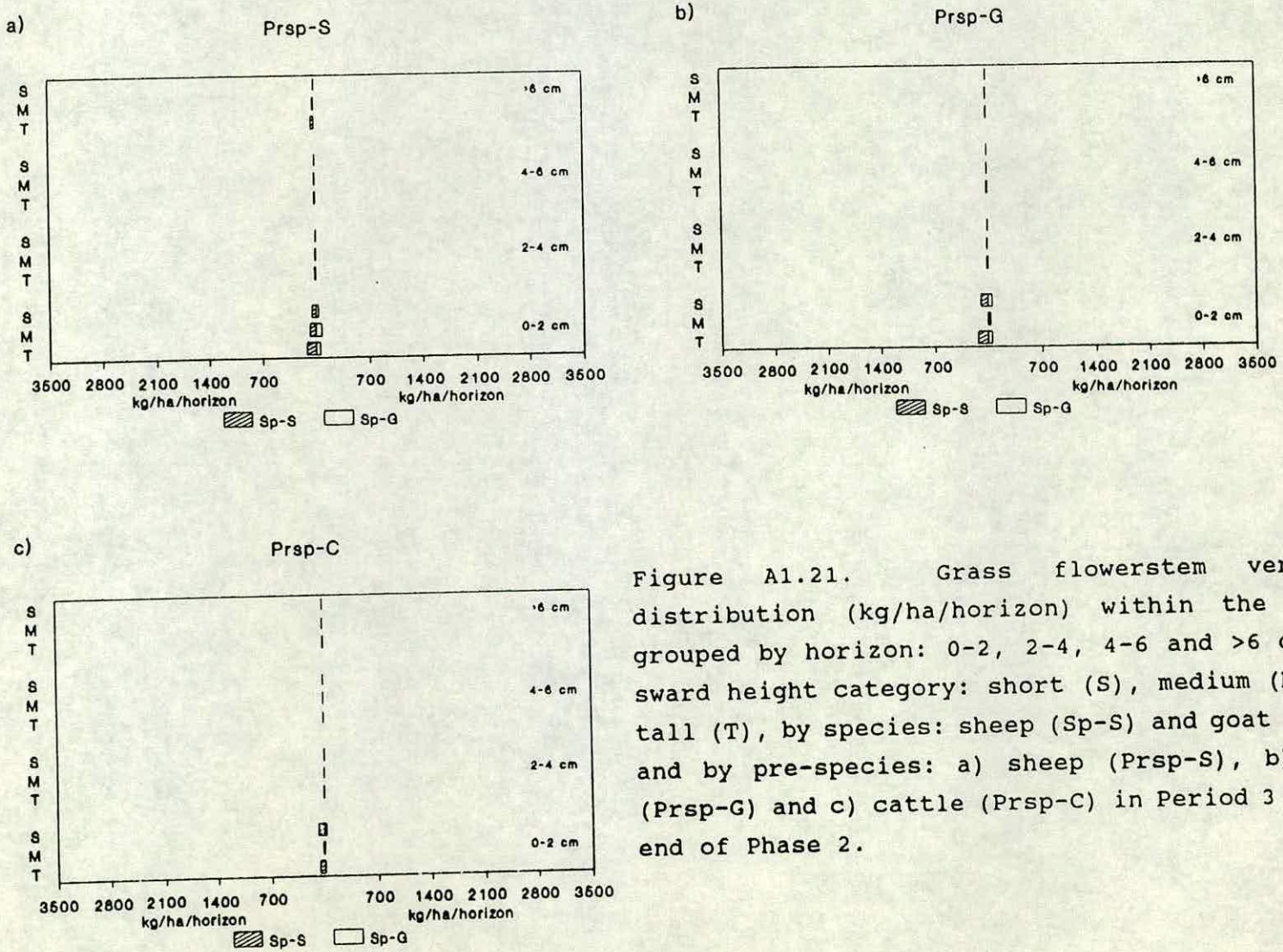


Figure A1.21. Grass flowerstem vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

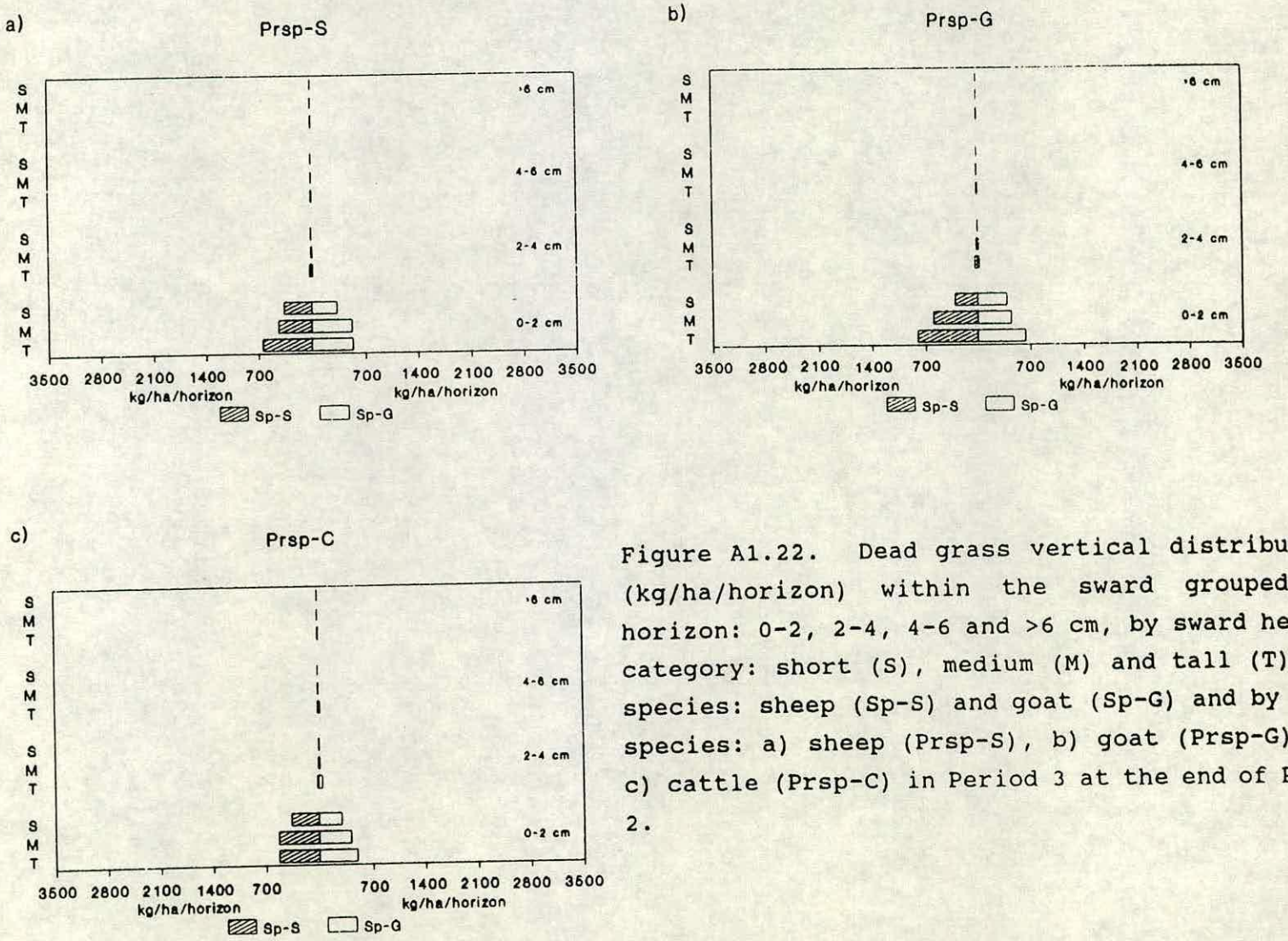


Figure A1.22. Dead grass vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

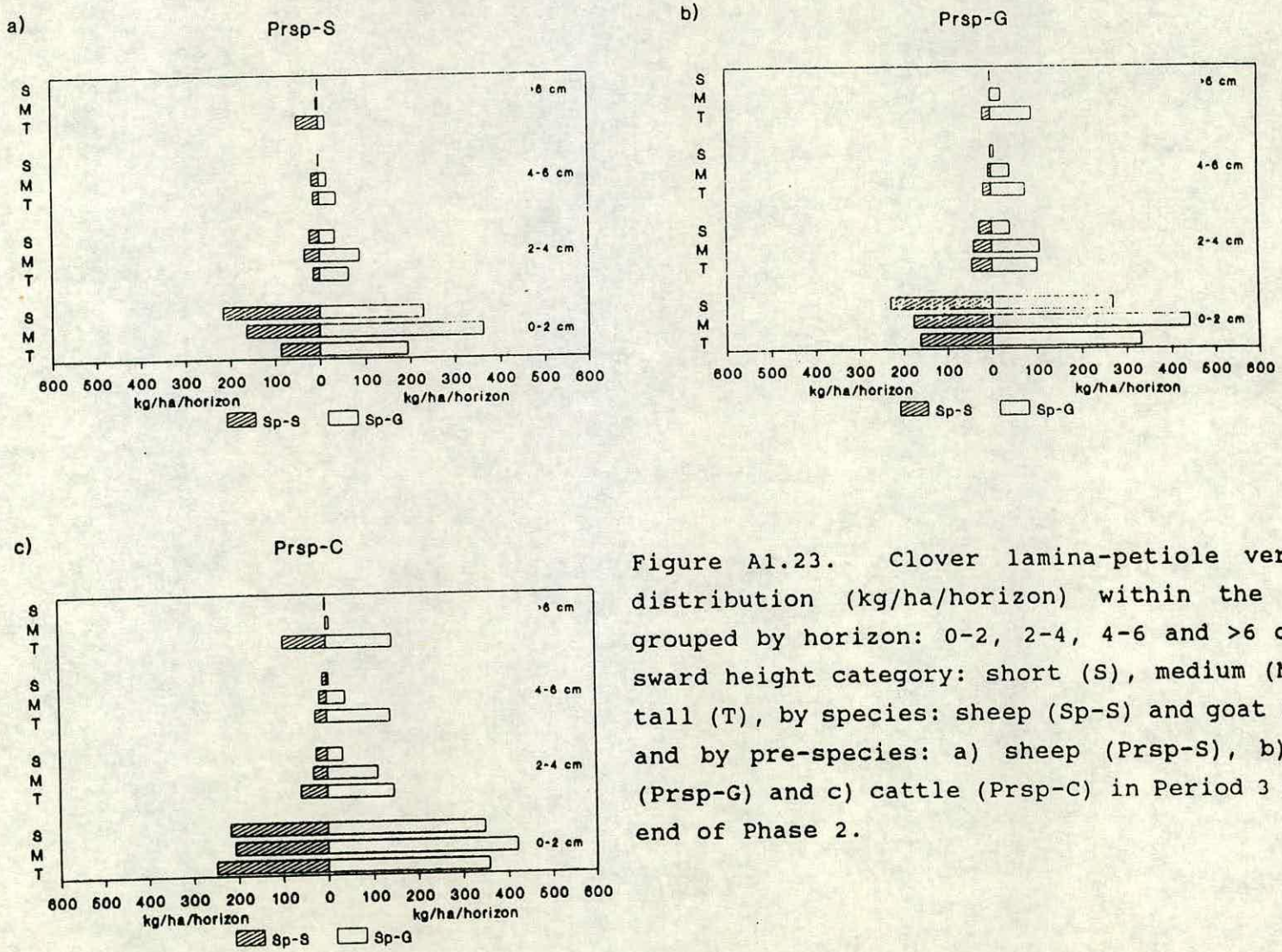


Figure A1.23. Clover lamina-petiole vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

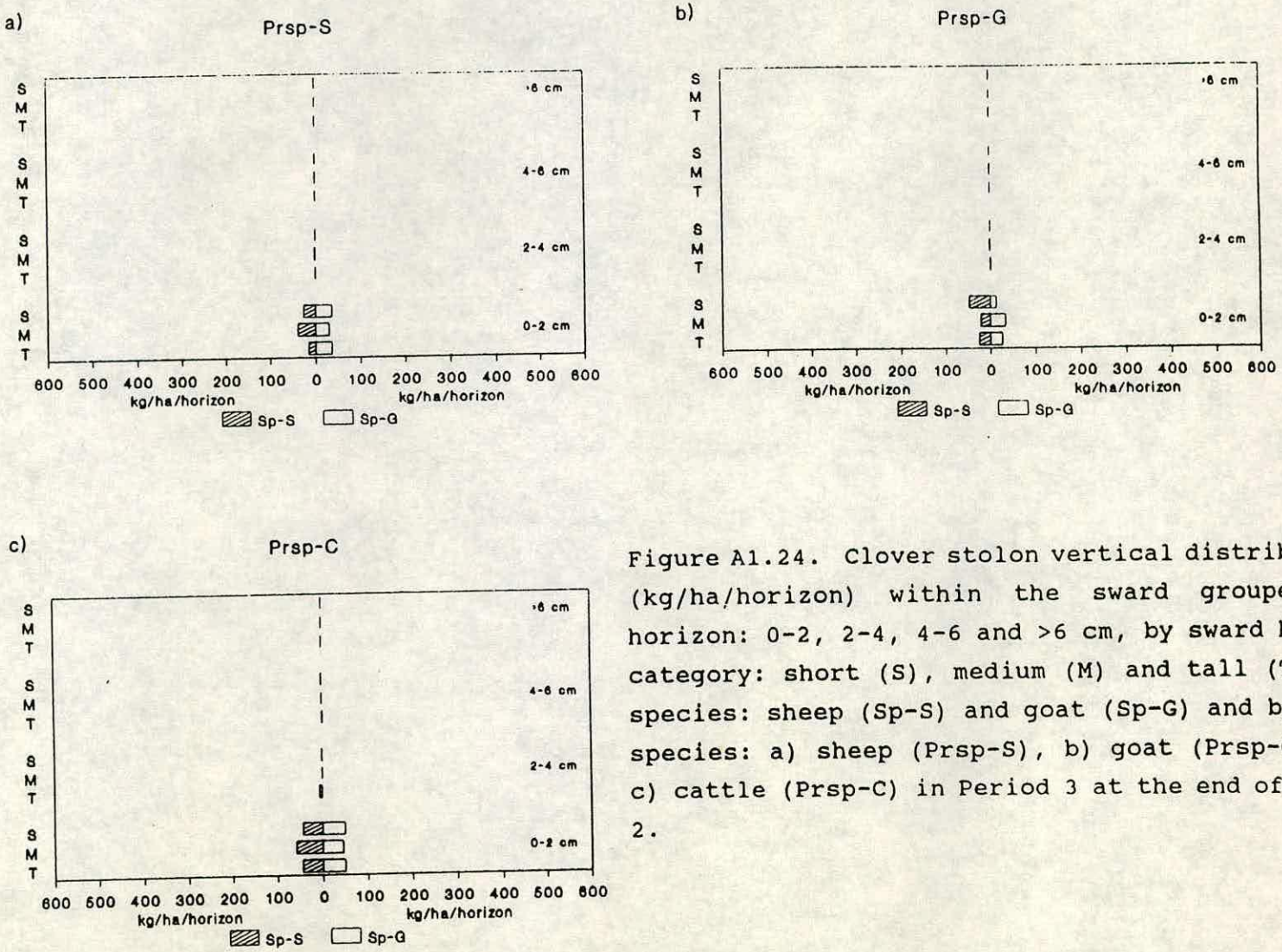


Figure A1.24. Clover stolon vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

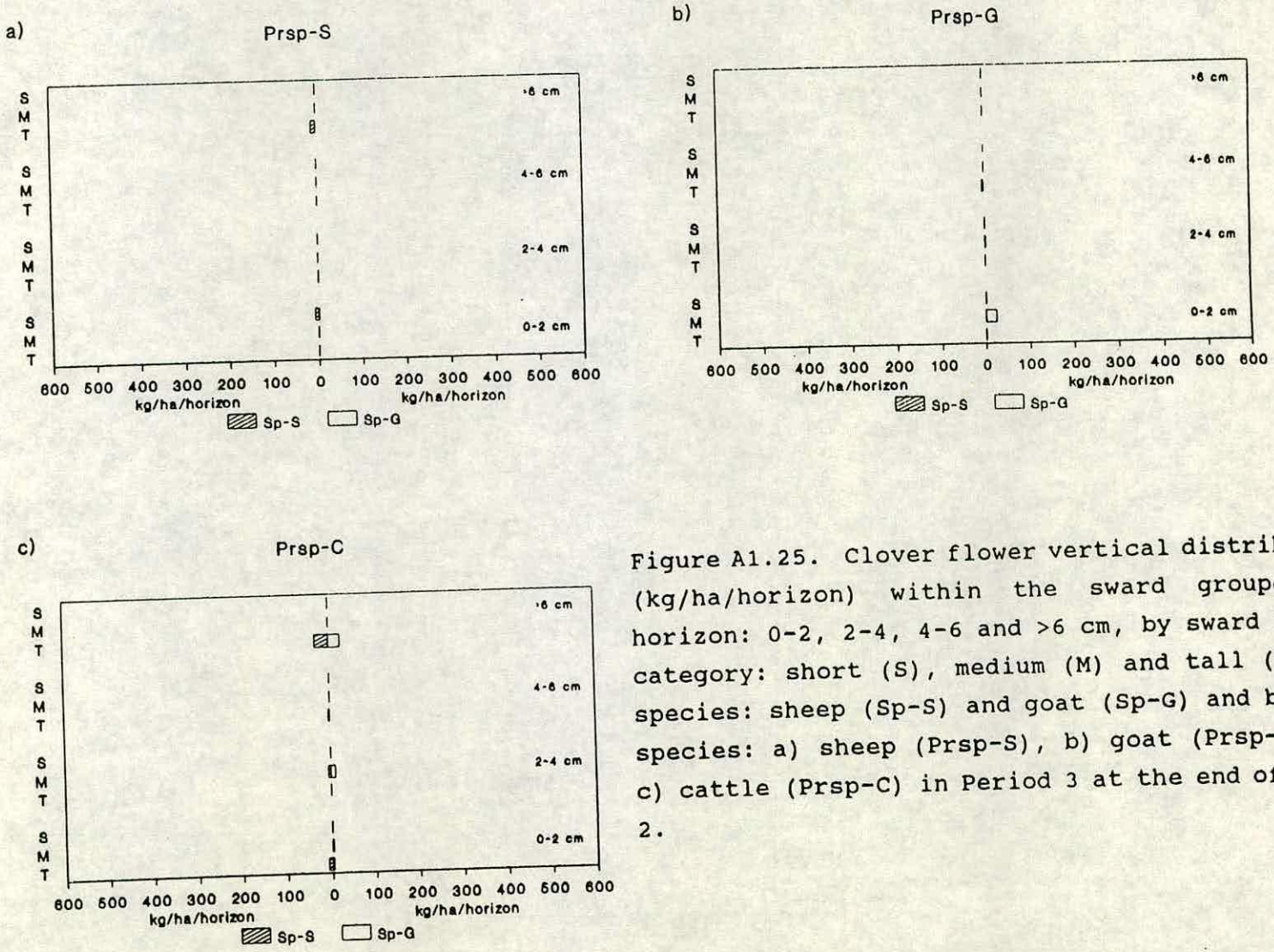


Figure A1.25. Clover flower vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

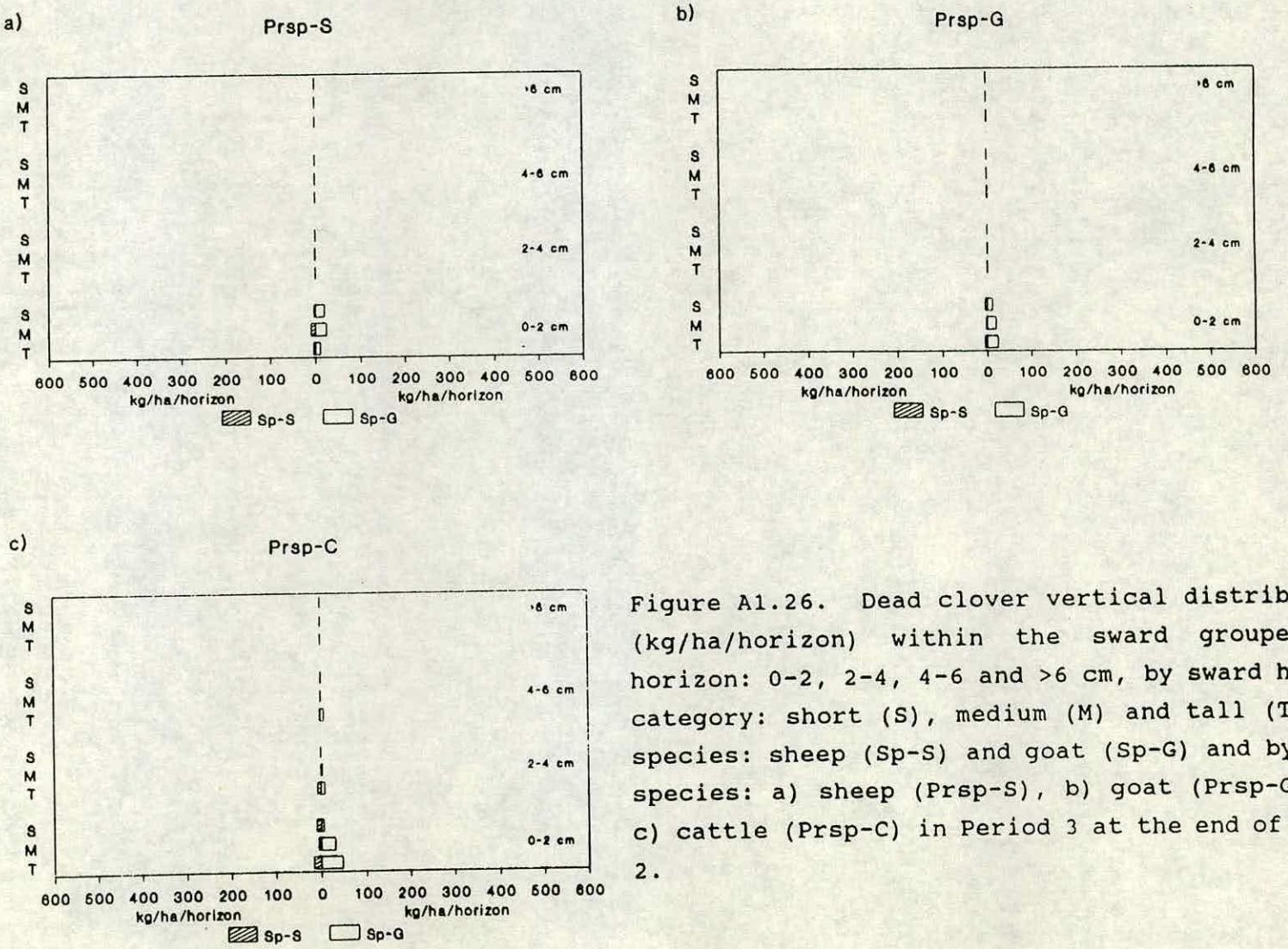


Figure A1.26. Dead clover vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

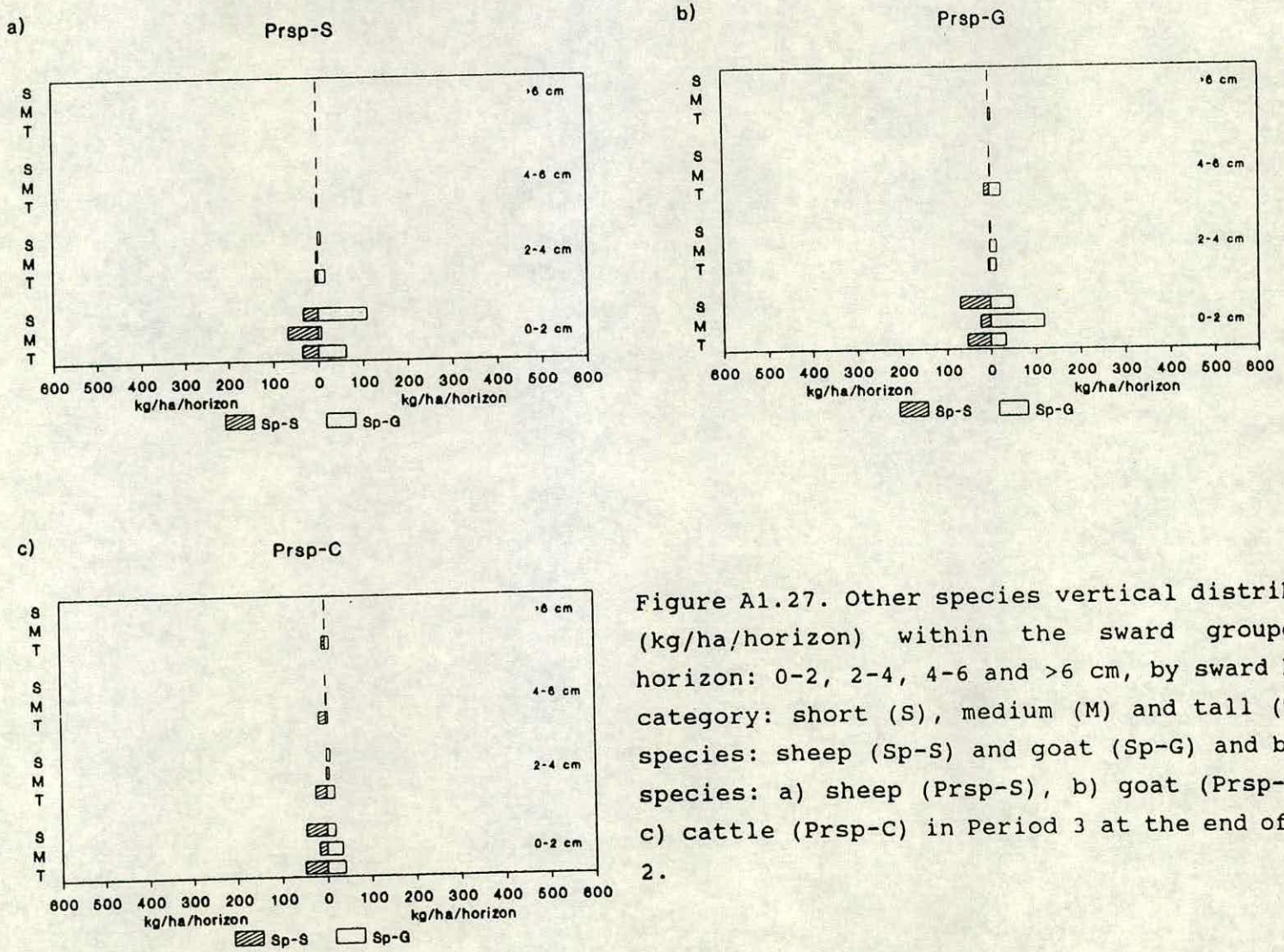


Figure A1.27. Other species vertical distribution (kg/ha/horizon) within the sward grouped by horizon: 0-2, 2-4, 4-6 and >6 cm, by sward height category: short (S), medium (M) and tall (T), by species: sheep (Sp-S) and goat (Sp-G) and by pre-species: a) sheep (Prsp-S), b) goat (Prsp-G) and c) cattle (Prsp-C) in Period 3 at the end of Phase 2.

Appendix 2.

Body condition scoring of goats.

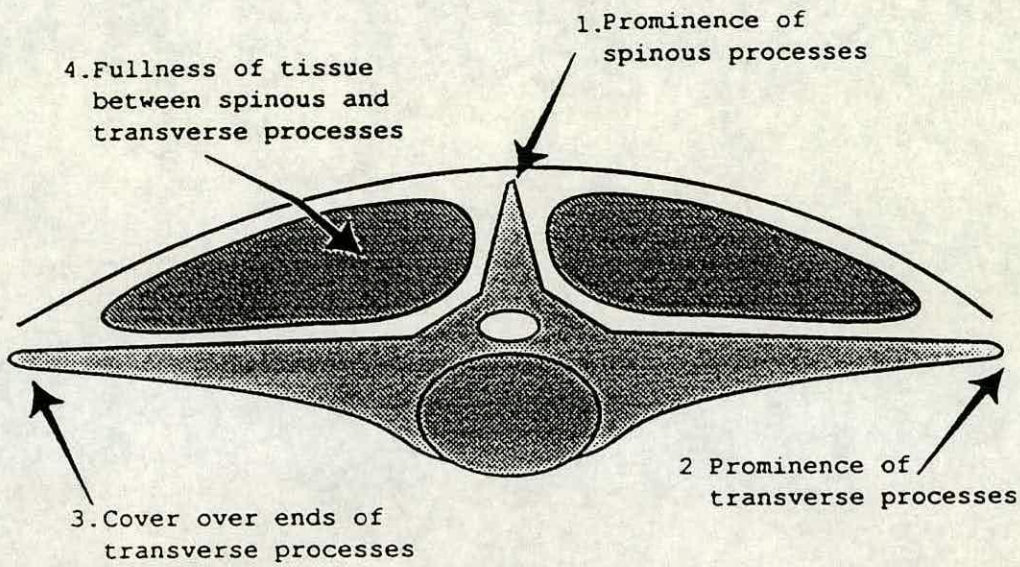
Body condition scoring is a technique used to assess subjectively the degree of fatness or condition of a live animal.

The condition scoring system used for goats is exactly the same as that originally devised in Australia and developed by Russel *et al.*, (1969) in UK for sheep. Goats and sheep have a different distribution of fat in the body. Sheep carry more of their fat subcutaneously, whereas goats store more fat internally, laying down more in the body cavity and around the kidneys. There are also differences in fat distribution between different breeds of sheep and between different breeds of goats. Russel (1990) suggested that it would be preferable to have one scoring system for both species and to set different 'target' scores for particular purposes for each species or type. He suggested that targets of around 1 unit of condition score lower are appropriate for goats compared to sheep.

The grading process

The condition of the goat is assessed by feeling the spine and lumbar processes with the fingers immediately behind the last rib and above the kidneys. Animals are evaluated in terms of the sharpness or roundness of the spinous processes of the lumbar vertebrae, the degree of fat cover in the angle between the transverse and spinous processes and the fullness of the eye muscle (see Figure A2.1).

Figure A2.1. The four stages in the assessment of body condition score.



(from Russel, 1990)

The definition of each score is:

- score 0: It is not possible to detect any muscular or fatty tissues between the skin and the bone.

- score 1: The backbone is prominent and sharp. The transverse processes feel sharp at the ends and the fingers easily pass under the ends. The eye muscle areas are shallow with no fat cover and the angle between the spinous and transverse processes is very acute.

- score 2: The spinous processes still feel prominent, but smooth, and individual processes can be felt only as fine corrugations. The transverse processes are smooth and rounded, and it is possible to pass the fingers under the ends with a little pressure. The eye muscle areas are of moderate depth, but have little fat cover and the angle between the spinous and transverse processes is less acute.

- score 3: The spinous processes are detected only as small elevations; they are smooth and rounded, and individual bones can be felt only with pressure. The transverse processes are smooth and well covered, and firm pressure is required to feel over the ends. The eye muscle areas are full, and have a moderate degree of fat cover. The angle between the spinous and transverse is slight.

- score 4: The spinous processes can just be detected, with pressure, as a hard line between the fat covered muscle areas. The ends of the transverse processes cannot be felt. The eye muscle areas are full and have a thick covering of fat. The area between the spinous and transverse processes are felt almost flat.

- score 5: The spinous processes cannot be detected even with firm pressure and there is a depression between the layers of fat in the position where the spinous processes would normally be felt. The transverse processes cannot be detected. The eye muscle areas are very full with very thick fat cover. There may be large deposits of fat over the rump and tail.

Appendix 3.

APPENDIX 3a

Experiment 1: an example of the analysis of variance procedure used on a component of the botanical composition in Period 3 at the end of Phase 2.

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Experiment 1

***** Analysis of variance *****

Dry matter values of total clover (lamina-petiole + stolon + flower + dead)

Variate: clover total

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plot stratum					
replicat	1	15457.	15457.	3.51	0.202
prespeci	2	70005.	35003.	7.96	0.112
Residual	2	8797.	4398.	0.59	
plot.subplot stratum					
specie	1	125227.	125227.	16.92	0.026
prespeci.specie	2	9101.	4550.	0.61	0.597
Residual	3	22199.	7400.	2.17	
plot.subplot.categ stratum					
categ	2	42325.	21162.	6.22	0.014
categ.prespeci	4	49129.	12282.	3.61	0.037
categ.specie	2	32965.	16483.	4.84	0.029
categ.prespeci.specie	4	5296.	1324.	0.39	0.812
Residual	12	40826.	3402.	1.67	
plot.subplot.categ.*Units* stratum					
horizon	3	2040476.	680159.	333.16	<.001
categ.horizon	6	69023.	11504.	5.63	<.001
prespeci.horizon	6	33676.	5613.	2.75	0.021
specie.horizon	3	112331.	37444.	18.34	<.001
categ.prespeci.horizon	12	10317.	860.	0.42	0.949
categ.specie.horizon	6	34156.	5693.	2.79	0.020
prespeci.specie.horizon	6	2137.	356.	0.17	0.983
categ.prespeci.specie.horizon	12	15644.	1304.	0.64	0.800
Residual	54	110242.	2042.		
Total	143	2849329.			

***** Tables of means *****

Variate: clover total

Grand mean 107.3

replicat	1	2
	117.7	96.9

categ	S	M	T
	83.8	114.0	124.2

prespeci	S	G	C
	81.0	106.0	134.9

specie	S	G
	77.8	136.8

horizon	0-2	2-4	4-6	>6
	312.3	60.2	27.6	29.2

categ	prespeci	S	G	C
S		74.7	82.4	94.3
M		99.3	118.0	124.6
T		68.9	117.7	185.9

categ	specie	S	G
S		75.5	92.1
M		71.3	156.6
T		86.7	161.7

prespeci	specie	S	G
S		62.7	99.2
G		70.9	141.1
C		99.8	170.0

categ	horizon	0-2	2-4	4-6	>6
S		299.3	31.0	4.3	0.6
M		353.3	73.4	23.0	6.2
T		284.2	76.3	55.6	80.7

prespeci	horizon	0-2	2-4	4-6	>6
S		253.1	43.4	14.1	13.2
G		312.7	61.9	26.8	22.7
C		371.0	75.3	41.9	51.5

specie	horizon	0-2	2-4	4-6	>6
S		235.6	37.4	14.2	24.1
G		388.9	83.0	41.1	34.2

	prespeci	S		G		C	
categ	specie	S	G	S	G	S	G
S		69.7	79.6	78.9	85.8	77.8	110.8
M		68.9	129.7	62.9	173.1	82.0	167.1
T		49.6	88.3	70.8	164.5	139.7	232.2

categ	prespeci	horizon	0-2	2-4	4-6	>6
S	S		270.1	28.0	0.6	0.0
	G		289.5	35.0	4.9	0.2
	C		338.2	30.1	7.4	1.6
M	S		315.1	62.8	16.6	2.7
	G		359.9	76.2	23.8	12.1
	C		385.0	81.1	28.5	3.7
T	S		174.1	39.4	25.2	37.1
	G		288.7	74.6	51.6	55.8
	C		389.7	114.8	89.9	149.3

categ	specie	horizon	0-2	2-4	4-6	>6
S	S		269.9	26.2	4.7	1.2
	G		328.6	35.8	3.9	0.0
M	S		229.2	40.1	13.8	1.9
	G		477.4	106.6	32.1	10.4
T	S		207.8	45.8	23.9	69.2
	G		360.6	106.7	87.2	92.2

prespeci	specie	horizon	0-2	2-4	4-6	>6
S	S		192.4	25.9	10.7	21.9
	G		313.8	60.9	17.5	4.6
G	S		226.3	39.1	11.7	6.5
	G		399.0	84.7	41.8	38.9
C	S		288.1	47.2	20.0	44.0
	G		453.8	103.5	63.8	59.1

categ	prespeci	specie	horizon	0-2	2-4	4-6	>6
S	S	S		254.5	23.1	1.2	0.0
		G		285.7	32.9	0.0	0.0
	G	S		283.7	28.9	2.9	0.3
		G		295.2	41.1	6.9	0.0
	C	S		271.4	26.6	9.9	3.2
		G		405.0	33.5	4.9	0.0
M	S	S		214.0	38.7	17.5	5.3
		G		416.2	86.9	15.8	0.0
	G	S		202.1	42.6	6.9	0.1
		G		517.7	109.7	40.7	24.1
	C	S		271.5	39.1	17.1	0.3
		G		498.5	123.1	39.8	7.1
T	S	S		108.7	15.8	13.6	60.3
		G		239.5	63.0	36.8	13.9
	G	S		193.2	45.8	25.2	19.0
		G		384.2	103.4	78.0	92.7
	C	S		321.4	75.8	33.1	128.4
		G		458.0	153.8	146.7	170.2

*** Standard errors of differences of means ***

Table	replicat	categ	prespeci	specie
rep.	72	48	48	72
s.e.d.	11.05	11.91	13.54	14.34

Table	horizon	categ prespeci	categ specie	prespeci specie
rep.	36	16	24	24
s.e.d.	10.65	21.61	19.86	22.17
Except when comparing means with the same level(s) of				
prespeci		20.62		24.83
specie			16.84	

Table	categ horizon	prespeci horizon	specie horizon	categ prespeci specie
rep.	12	12	18	8
s.e.d.	19.92	20.94	19.38	32.54
Except when comparing means with the same level(s) of				
categ	18.45			
prespeci		18.45		34.40
specie			15.06	
categ.prespeci				34.40
prespeci.specie				29.16

Table	categ prespeci horizon	categ specie horizon	prespeci specie horizon	categ prespeci specie horizon
rep.	4	6	6	2
s.e.d.	35.10	30.08	31.65	50.89
Except when comparing means with the same level(s) of				
prespeci	34.51		33.57	52.10
specie		28.18		
categ.prespeci	31.95			52.10
categ.specie		26.09		
prespeci.specie			26.09	48.80
prespeci.horizon	34.51		33.57	52.10
specie.horizon		28.18		
categ.prespeci.specie				45.18
categ.prespeci.horizon				52.10
prespeci.specie.horizon				48.80

APPENNDIX 3b

Experiment 2: an example of the analysis of variance procedure used on a component of the botanical composition in Period 4 at the beginning of Phase 2.

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Experiment 2

***** Analysis of variance *****

Dry matter values of total clover (live plus dead) in Period 4 (at the start of Phase 2)

Variate: clover total

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plot stratum					
replicat	1	16894.	16894.	4.90	0.078
prespeci	1	117233.	117233.	34.00	0.002
height	2	106373.	53186.	15.43	0.007
prespeci.height	2	2262.	1131.	0.33	0.735
Residual	5	17240.	3448.	2.11	
plot.*Units* stratum					
horizon	3	1542749.	514250.	314.48	<.001
prespeci.horizon	3	46289.	15430.	9.44	<.001
height.horizon	6	38037.	6339.	3.88	0.012
prespeci.height.horizon	6	45802.	7634.	4.67	0.005
Residual	18	29434.	1635.		
Total	47	1962314.			

***** Tables of means *****

Variate: clover total

Grand mean 208.4

replicat	1.00	2.00
	189.7	227.2

prespeci	sheep	goat
	159.0	257.8

height	4-4	4-8	8-8
	145.2	258.2	221.9

horizon	0-2	2-4	4-6	>6
	514.7	153.5	91.3	74.2

prespeci	height	4-4	4-8	8-8
	sheep	95.2	217.5	164.4
	goat	195.3	298.9	279.3

prespeci	horizon	0-2	2-4	4-6	>6
	sheep	412.4	112.3	65.1	46.2
	goat	617.0	194.7	117.5	102.3

height	horizon	0-2	2-4	4-6	>6
	4-4	515.9	52.8	11.4	0.8
	4-8	536.1	233.7	145.4	117.5
	8-8	492.1	174.0	117.0	104.3

prespeci	height	horizon	0-2	2-4	4-6	>6
	sheep	4-4	355.2	21.7	2.7	1.0
		4-8	507.9	201.7	98.3	61.9
		8-8	374.2	113.5	94.3	75.6
	goat	4-4	676.6	83.8	20.2	0.6
		4-8	564.3	265.7	192.5	173.0
		8-8	610.1	234.6	139.6	133.1

*** Standard errors of differences of means ***

Table	replicat	prespeci	height	horizon
rep.	24	24	16	12
s.e.d.	16.95	16.95	20.76	16.51

Table	prespeci treatmen	prespeci horizon	height horizon	prespeci height horizon
rep.	8	6	4	2
s.e.d.	29.36	26.38	32.31	45.70

Except when comparing means with the same level(s) of

prespeci		23.35		
height			28.59	
prespeci.height				40.44