IMPACT OF STOCKING RATE, LIVESTOCK TYPE AND LIVESTOCK MOVEMENT ON SUSTAINABLE UTILISATION OF SOURVELD

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A thesis submitted in fulfilment of the academic requirements
for the degree of

DOCTOR OF PHILOSOPHY

In the
Department of Range and Forage Resources
Faculty of Agriculture
University of Natal
Pietermaritzburg

1999

ABSTRACT

Data collected between 1992/93 and 1996/97 from two long-term grazing trials were used to investigate the interaction between grazing animals and veld grass. In the first trial, the impacts of stocking rate and time of stocking in spring on both livestock performance and veld vigour (defined as the ability of a grass plant to regrow after defoliation) and condition were investigated. In the second trial comparisons were made, firstly between the impacts of sheep and cattle grazing, and secondly between various types and frequencies of rest, on veld vigour and condition.

Treatments applied in the first trial comprised four stocking rates, namely 7, 10, 13 and 16 sheep ha^{-1} for the duration of the grazing season, and two times of stocking, namely as early as possible after spring burning and three weeks later. Sheep grazed each treatment continuously throughout the growing season. Treatments were applied to alternate blocks in a two-year cycle with each block resting for a year within a grazing cycle. Animal performance (mass gains over the season) was measured to quantify livestock performance. Herbage availability was measured on a species basis at intervals throughout each season using a dry-weight-rank procedure to determine grazing patterns. Residual effects of the grazing treatments on vigour were determined by measuring herbage regrowth on a species basis during the rest season which followed a season of grazing and comparing these measures to a previously ungrazed control treatment. Effects of the grazing treatment on proportional species composition were determined using a nearest plant point technique.

Stocking rate had a non-linear effect on livestock performance, with livestock performance on the lightest stocking rate being less than on the two intermediate stocking rates. The mass gains on the heaviest stocking rate were generally the smallest. Delaying the time of stocking in spring resulted in smaller mass gains during the resultant shorter season. The sheep from both the early and late time of stocking groups had similar mean masses at the end of the season. The advantage of stocking early can thus be attributed more to saving the cost of alternative feed for the interim period than to additional mass gains due to stocking early. Quantification of livestock performance in terms of selected and available feed quality, quantity and species availability throughout each season was extremely complex due to multiple thresholds in the measured variables and no simple cause and effect relations could be established that would hold for spatial or temporal extrapolation.

The negative impact of grazing on veld vigour was severe. Stocking rate and time of stocking had a secondary impact with the vigour loss positively related to increasing grazing pressure. The main factor influencing vigour loss was grazing, irrespective of time of stocking or stocking rate, as opposed to no grazing. The impact of grazing on vigour was severely negative in the palatable species, variable in the species of intermediate palatability and positive in the unpalatable species that were rarely, if ever, grazed. The stocking rate and time of stocking rate had an impact on the proportional species composition, with the more palatable species declining in proportion. There was an observable relation between impact of grazing on vigour and on species composition.

Treatments applied in the second trial involved applying a full growing season rest in alternate years, half a growing season rest (late season) in alternate years and no rest to veld grazed by sheep or cattle at similar stocking rates. Residual effects of the treatments on veld vigour were determined by measuring species regrowth using a dry-weight-rank technique during the season following treatment application, and comparing it to controls ungrazed for one and two seasons respectively. Changes in proportional species composition were determined using a nearest plant point technique.

The vigour of veld grazed by sheep declined rapidly relative to veld grazed by cattle. The vigour of palatable species was severely impacted, vigour of intermediate species was variably impacted and vigour of unpalatable species increased dramatically on veld grazed by sheep compared to the control treatments. Similar trends occurred in veld grazed by cattle, but to a lesser degree. Resting was beneficial for vigour recovery in both sheep and cattle treatments but it seems that the grazing treatment between rests has a greater influence on the veld vigour and condition than the rest itself. The veld grazed by sheep remained at a substantially lower productivity level than veld grazed by cattle. This was particularly evident in the change in productivity balance between palatable and unpalatable species in the sheep treatments, where palatable species vigour declined and unpalatable species vigour increased relative to veld grazing by cattle. Species composition of veld grazed by sheep deteriorated over the trial period in contrast to the veld grazed by cattle, which improved in species composition.

Grazing management recommendations for sourveld should include a bias towards cattle, optimising stocking rate for improved performance and resting for enhancing vigour of the palatable grasses.

DECLARATION

I hereby declare that this thesis and the associated research comprises my own original work, except for the assistance which is acknowledged or where due reference is made in the text. I also declare that the results obtained in this thesis have not been previously submitted by me in respect of a degree at any University.

Kevin Peter Kirkman

ACKNOWLEDGEMENTS

My sincere appreciation is extended to the following persons and institutions:

The Mpumalanga Department of Agriculture for support of the research programme and for permission to use the data for the purposes of this dissertation.

Several of South Africa's leading Grassland Scientists were involved in some way or another in the study and I would like to thank them for their assistance and inspiration. Firstly, Denis Barnes inspired this line of research with his earlier work. He assisted with the design of the trials and was instrumental in motivating me and equipping me with the necessary skills to undertake the research programme. He has remained my mentor and friend, and has maintained an active interest in the research long after his retirement. Dr Arno Moore made many contributions to the interpretation of the data and the resultant implications of the results to practical grazing management recommendations. He also ensured that the necessary finance, personnel and infrastructure were made available. Professor Tainton supervised the initiation of the research until his retirement. Professor O'Connor took over as supervisor and assisted in the later stages of the research.

Long discussions with several colleagues from Cedara and Döhne Agricultural Development Institutes, including Dr Mark Hardy and Felix Hobson, were of great benefit.

The Grassland Society of Southern Africa, through its excellent scientific congresses and journal, is a source of inspiration for all grassland scientists in Southern Africa.

Mrs Marie Smith of the Agrimetrics Institute of the Agricultural Research Council gave me invaluable (and understandable) statistical advice.

My colleagues at Nooitgedacht Agricultural Development Centre and Athole Research Station assisted me in every way possible. In particular, Vincent Cockcroft, Anneke Engelbrecht and Annelene Swanepoel assisted with all aspects of the research, and spent many hours on their knees in the veld. Samuel Zwane, Piet Skosana, William Msibi and Mathew Masondo assisted with the running of the trials. Amanda Wolmarans spent many hours capturing and processing data. She also assisted in preparing figures and in the final layout. Mr SD Niemand and the staff at Athole Research Station assisted with the day to day management of the trial at Athole.

My wife, Sharon, was patient and supportive throughout my time as a student.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Background

Veld is a key element in the provision of cheap feed for the livestock industry in South Africa. This, combined with the unique role of veld in the ecosystem, particularly with regard to water provision and soil conservation, make it one of South Africa's most valuable natural resources. About 84 % (or some 76.6 million ha) of the land available for agriculture in South Africa is utilised as natural grazing (Adler 1985).

The area of land available for agriculture is shrinking at an alarming rate (about 20 000 ha per year (du Plessis 1982)) due to a steady increase in other forms of land use such as roads, railways, mining, industrial and urban development. The growing population is putting pressure on the agricultural sector to increase food production on this shrinking land area. In South Africa in 1970 there was 5.5 ha of agricultural land available per person of which 0.6 ha was cultivated land. With the present rate of population growth it is predicted that by the year 2020 this will have decreased to 1.5 ha per person of which only 0.2 ha will be arable (Adler 1985).

It is obvious therefore that the conservation and proper utilisation of veld is vitally important, particularly for the sustained productivity of the livestock industry in South Africa. Moreover, in the light of rising costs of intensification in the form of planted pastures, its importance in the livestock industry is increasing.

Sourveld is defined as veld which loses palatability and quality when mature, and consequently provides quality grazing for between six and eight months of the year. While the production and consequent grazing capacity of sourveld is generally high, the low winter quality and low acceptability of forage to animals complicates livestock production. Sourveld predominates in the high rainfall areas at high altitude in the eastern and southern parts of South Africa, largely but not entirely in the fire climax grasslands, which are transitional to woodland or forest. Some occur as pure grassland, while others are wooded. The coastal regions on the eastern seaboard of South Africa are also classified as sourveld (Tainton 1981a).

Evidence, albeit largely circumstantial, indicates that in general, degradation of sour grassveld has resulted in a grazing value well below its potential (e.g. Rethman & Kotze (1986); Aucamp & Danckwerts (1989); Barnes (1990)). This represents a serious economic loss to the livestock industry and to the country. In addition, the geographic position of the sour grassveld covering the major catchment areas of South Africa puts an extra dimension on the importance of maintaining good vegetation cover in the sourveld regions.

The degradation of sourveld essentially takes the form of a decrease in preferred species and an increase in unpreferred or less preferred species. This is perceived to be caused largely by over- or selective grazing (Edwards 1981a; Tainton 1981b). Reversing this trend is possibly one of the most important challenges facing veld and livestock research and extension in South Africa.

1.2 Historical perspective of veld management in Southern Africa

The continuing degradation of sourveld has been a matter of great concern to research and extension personnel for several decades. In an effort to reverse the trend the major thrust has been on trying to persuade farmers to adopt grazing systems, and especially multi-paddock grazing systems with relatively short periods of stay. These were presumed to be a means of minimising selective grazing and preventing loss of vigour of the preferred species.

The farmer's acceptance of these multi-paddock systems has, however, been minimal (Roberts 1969; Tainton 1985; Scholtz 1987). Recent critical evaluations of the empirical base for such recommendations have shown that they contained certain flaws (Barnes 1992; O'Reagain & Turner 1992). Indications are that had farmers applied some of those recommendations, there could be no guarantee of an improvement in veld condition or animal performance.

1.2.1 A perspective on locally recommended grazing systems

The role of fire and grazing procedure (i.e. livestock numbers, livestock type and livestock distribution) as management tools are probably the most contentious issues regarding grazing management recommendations in South Africa. In particular, the impact of varying paddock numbers, periods of absence and periods of stay have been debated for many years without definitive conclusions being reached.

1.2.1.1 Role of fire in sourveld

Fire plays an important role in the maintenance of sour grassveld (Staples 1926; Staples 1930; Cook 1939; Roux 1969; Scott 1970; Tainton 1981c; Everson & Tainton 1984; Everson *et al.* 1985), particularly with the control of certain woody invader species (Edwards 1981b). Fire is also of primary importance in livestock production, particularly sheep production. Sheep performance on unburnt veld is significantly lower than that on comparable burnt veld (Barnes & Dempsey 1992; Zacharias 1994). Malherbe (1971) found that a decrease in fire frequency within a grazing system resulted in reduced sheep performance. The removal of residual dead material by fire during the dormant season, although untested, is likely to result in more uniform grazing during the following season relative to unburnt veld.

While the burning of veld has often been condemned as being a major cause of veld degradation and consequent soil erosion, it seems that judicial use of fire in sourveld regions plays an important role in the maintenance of sourveld as well as for ensuring satisfactory sheep performance.

The role of fire in sourveld was recently studied by Barnes & Dempsey (1992) and by Zacharias (1994), and will not be discussed further in this study.

It must, however, be mentioned that burning of veld as a standard management practice may come under increasing pressure in the future because of its impact on air quality. Should veld burning be restricted in the future, the viability of sheep production in the sourveld regions will become questionable, particularly where sheep are grazed alone. The role of mixed species grazing may become more important under these conditions.

1.2.1.2 Grazing procedure

Many veld management systems have been conceived and recommended in South Africa (e.g. Scott 1955; West 1955; Edwards 1981b). With earlier approaches, systematic resting of veld was emphasised. More recently (since the mid-nineteen sixties) the emphasis has changed to controlling the degree of spatial and temporal utilisation of veld within a grazing season, largely by manipulation of the grazing procedure in a rotational grazing system. With this change in emphasis came the perception that periods of stay and absence in a rotational grazing system are the overriding factors determining veld reaction to grazing and thus veld condition in the long term. O'Reagain & Turner (1992) pointed out that the perception exists that stocking rate is only of secondary importance relative to the grazing procedure. This pre-occupation with grazing procedure led to a focus on within season management, with attempts to create a perfect grazing regime within each season.

It has been suggested that the rotational grazing philosophy predominant in South Africa originated from a pre-occupation with the problems of selective grazing (Booysen 1969; Booysen, Tainton & Foran 1975). Booysen (1969) questioned whether South African veld differs from that of other countries in such a way as to make selective grazing in South Africa more prevalent and more of a serious problem. He posed the question whether South African grassland scientists and graziers have overemphasised the problem to the extent that they ignore other important problems, requirements and objectives of management. As an example, the effect of grazing (irrespective of grazing procedure) on the vigour of grass was effectively ignored for many years.

Most researchers and advisors in South Africa favour rotational grazing of veld and in particular multi-paddock rotational grazing with at least six to eight paddocks per animal group for most veld types. Examples of veld management recommendations based on this concept include Transvaal Region (1984); Barnes (1989); Danckwerts (1989); Hobson (1989); Hobson & Swart (1989); Stuart-Hill (1989); Teague (1989); Trollope (1992). In recent years grazing management recommendations have been based mainly on one of two concepts, namely non-selective grazing (NSG) as proposed by Acocks (1966) (later termed high utilisation grazing (HUG) by Booysen (1969)), and high performance grazing (HPG) proposed by Booysen (1966; 1969). The two concepts are diametrically opposed. With HUG the emphasis is on complete utilisation of the herbage on offer. With HPG the emphasis is on lenient utilisation. In both systems, the objectives are to increase animal production and maintain veld condition (Edwards 1981b). This is supposedly achieved with HUG by firstly increasing the utilisation of the herbage on offer and secondly, by forced utilisation of the less preferred species. With HPG this is supposedly achieved by firstly increasing the growth rate of the preferred plants (by lenient or lax grazing) and secondly, by deliberate under utilisation of the less preferred plants thereby inducing them to become moribund (Edwards 1981b). Both systems are ideally based on multi-paddock layouts and follow a rotational grazing procedure, with the main differences being that the periods of stay and absence under HUG are relatively long compared to those under HPG, resulting in the required differences in degree of utilisation (Edwards 1981b).

Controlled selective grazing (CSG) is a grazing system suggested by Pienaar (1968) and is in practice similar to the high performance grazing (HPG) system put forward by Booysen (1969). It has also been referred to as the Soutpan system (Drewes 1991). Essentially the three systems are based on the same philosophies and principles and are practically the same. The CSG system is based on the moderate utilisation of the preferred species and the deliberate non-utilisation of the less preferred species in an attempt to induce them to become moribund. Burning is removed completely from the system for this supposed effect to operate (Low 1975; Edwards 1981b).

Short duration grazing (SDG) is a concept first suggested by Savory (1978), based on a multi-paddock rotational grazing procedure. The emphasis is on relatively short periods of occupation aimed at preventing more than one defoliation of the grasses, and relatively long periods of absence. In the initial stages of the development of SDG, it was based on the concept of NSG/HUG, but later was based more on the HPG concept (Savory 1978). Additional objectives such as the laying of litter and chipping the soil surface by livestock have often been linked to SDG. It has also often been stated that increase in paddock numbers under the SDG system can result in radically increased grazing capacity. Vaughan-Evans (1978) (cited by Gammon 1984) for example suggested that potential grazing capacity with thirty-seven paddocks per herd would be double that with seven paddocks.

While there may still be some confusion regarding the merits and demerits of the various proposed systems, CSG was some years ago advocated by the Department of Agriculture as a blanket recommendation for most veld types in South Africa. Examples of this include Mostert *et al.* (1971); Low (1975); Grunow (1980) (cited by Tainton (1985)); Transvaal Region (1984); Tainton (1985)). These recommendations included sweetveld and sourveld, irrespective of the livestock concerned.

The above concepts are, however, largely untested scientifically both as management systems and in terms of the underlying hypotheses (O'Reagain & Turner 1992). It has recently been stated that multi-paddock rotational grazing, which forms the basis of probably all currently recommended veld management systems in South Africa, is not superior to few-paddock or continuous grazing systems (Barnes 1992; O'Reagain & Turner 1992). Further examination of the underlying principles of rotational grazing reveals several inconsistencies.

Rotational grazing is generally applied with one or both of the following objectives in mind. The first objective is to increase productivity by inducing defoliation patterns that lead to increased production of herbage of the desired quality and the second objective is the maintenance or improvement of the botanical composition and vegetative cover of the grazing resource (Barnes 1982).

Studies comparing continuous and rotational grazing as well as multi-paddock with few-paddock systems have shown that the differences in defoliation patterns under the above procedures were minor (Gammon & Roberts 1978a; 1978b; 1978c; Gammon & Twiddy 1990). It was found that there was only a slight decrease in frequency of defoliation of the preferred species with rotational as compared with continuous grazing. The severity of defoliation of the preferred species was slightly greater with rotational grazing in the early season but the reverse occurred in the late growing season. Continuous grazing did not result in frequent severe defoliation of the preferred plants.

Although rangeland in the USA differs from local sourveld, it may be relevant to refer to studies conducted in the USA on natural pasture. Heitschmidt *et al.* (1987a; 1987b) found that increasing the number of paddocks from 14 to 42 did not have any significant effect on aboveground biomass dynamics, forage production, harvest efficiency or forage quality. The same authors (Heitschmidt *et al.* 1987c) compared a 16 paddock rotational grazing system (at a stocking rate of 3.7 ha cow^{-1} $year^{-1}$) with continuous grazing (at a stocking rate of 5.9 ha cow^{-1} $year^{-1}$) and found no difference between treatments in herbage growth dynamics. Differences in amount and quality of standing crop were attributed to stocking rate and not grazing procedure.

These results indicate that the scope for manipulation of defoliation patterns by rotational grazing is limited. This is reinforced by consideration of the heterogeneous nature of the veld, changes in diet preferences of animals during the year, variations between years in the amount of herbage present, and the need to allow herbage to accumulate over the growing season for use during the dormant season (Barnes 1982). Also, the effects of specific defoliation patterns on yield and quality may vary widely for different grasses, and even ecotypes of the same species (Mufandaedza 1976). It is clearly impossible to attempt to impose different defoliation patterns on each of the important species and ecotypes for utilising each of these optimally.

There are many possible rotational grazing systems depending on the number of paddocks available per herd and the specific procedure adopted. During the growing season, it seems that the key factor affecting animal performance in a rotational grazing system is grazing intensity (number of animal unit days per unit area in each grazing cycle). This is shown by a negative linear relation between grazing intensity and mass gain per animal during the mid- and late growing season (Denny & Barnes 1977). For a given grazing intensity, animal performance should therefore be similar, regardless of the number of paddocks used. This strongly suggests that selection and defoliation patterns do not vary between rotational grazing procedures involving different numbers of paddocks per herd, but rather in the way the same grazing intensity is applied (Barnes 1982).

The overall picture is that when livestock are moved into a paddock, they first graze the plants and parts of plants acceptable to them. As the period of stay increases, there is a progressive decrease in the amount of acceptable herbage available. After a critical grazing intensity is reached, the animals are subjected to selection stress and intake is consequently reduced. Increasing the number of paddocks per herd does little to change the situation. It merely reduces the period before the critical grazing intensity is reached within each paddock. It seems that the only way to significantly change defoliation pattern in a rotational grazing system is to increase grazing intensity beyond the critical level, i.e. induce selection stress. This would reduce animal performance and in the long run would probably result in damage to the vegetation (Barnes 1982). In addition, as the number of paddocks increases, the rate of change in grazing intensity increases. This in fact creates more opportunities for managers to mismanage grazing intensity thereby depressing animal performance.

Claims made for substantial increases in grazing capacity through the use of intensive rotational grazing have not been substantiated by the results of experiments (Denny 1976 (cited by Barnes 1982); Denny & Steyn 1977; Gammon 1978; Barnes & Denny 1991). Claims that floristic composition improves with intensive rotational grazing have also not been substantiated by experimental results (Clatworthy 1975 (cited by

Barnes 1982); Denny & Barnes 1977; Denny *et al.* 1977; Denny & Steyn 1977; Barnes & Denny 1991). It is also important to note that, all other things being equal, individual animal performance under continuous grazing is generally as high or higher than with rotational grazing (Barnes 1982; Hart *et al.* 1988). Coughenour (1991) states that many tests of rotational grazing have failed to show any clear advantages. Gammon (1978), in a review of comparative grazing management experiments in various parts of the world, found no conclusive experimental evidence that any one form of rotational grazing was superior to any other. In addition, Mentis (1991) has presented a model suggesting that few paddock systems are financially better than systems with many paddocks.

It can be concluded therefore that accurate control of defoliation patterns on sourveld by means of rotational grazing is an unattainable ideal. Grazing procedure within a season should therefore be regarded as having secondary importance in grazing management recommendations.

1.2.2 Requirements of grazing management recommendations

It is important that land users see veld management recommendations as purposeful, practicable and financially advantageous. The multi-paddock CSG grazing systems are generally not considered by farmers to be appropriate in the sourveld regions and Düvel & Scholtz (1992) stated that promoting such systems in these areas was a case of "selling the unsellable".

It seems logical, therefore, to examine the requirements of producers regarding veld management and quantify the effects of grazing on veld, identify the major factors affecting the producer and the veld, and formulate simple grazing management recommendations accordingly. These recommendations should hold obvious financial advantages to the producer who implements them, as well as facilitating the maintenance or improvement of veld condition.

Sourveld areas of South Africa support a variety of agricultural enterprises including sheep and cattle production (both alone and mixed) on a large and small commercial scale, as well as communal land used for grazing purposes. Game production on a commercial scale appears to be unimportant currently in the sourveld regions, although there are indications that game production in the sourveld areas is increasing. While large areas are managed for conservation purposes and water catchment control (e.g. the Natal Drakensberg), I will concentrate on the livestock production areas.

One of the main problems facing stock farmers in sourveld regions is the provision of winter feed, and much research has been carried out in response to this problem. While many alternative winter feed sources have been developed, they are often costly. Veld remains a low cost source of feed on any farm, and it makes economic sense to investigate methods of utilising veld throughout the year as the basis of any fodder-flow programme.

While it is obviously important to consider the maintenance or improvement of veld condition, the results of a survey by Düvel & Scholtz (1992) in the Volksrust area indicated that the main aspirations of most farmers in this area are financially related. None of the farmers interviewed listed veld improvement as one of their aspirations. Appealing to the conservation ethic of such producers in an attempt to facilitate veld improvement will thus only have a minor effect on their attitude after financial considerations.

Many of South Africa's large-scale commercial farmers are in financial trouble, small-scale commercial farmers have limited access to capital, and the control of communal land areas is complex. It becomes obvious that any veld-management recommendations aimed at halting or reversing resource degradation will have to be cheap to implement (non-capital intensive), easy to understand and implement, must show obvious financial advantage to commercial farmers and must show tangible benefits to communal land users.

1.2.3 Effects of grazing management

1.2.3.1 Animal performance

It is common practice for sourveld sheep producers to burn an appreciable portion of their veld annually to provide short, leafy grazing free of residual dead material and then stock it two to three weeks after the start of growth in spring. Grassland scientists and extension personnel (e.g. Trollope (1984)) have generally condemned this practice. However, the effect of not burning, or alternatively not stocking veld soon after burning, on sheep performance is dramatic. Sheep performance on unburnt veld can be as low as 25 % of that on comparable burnt veld, while delaying stocking by two to three weeks after early stocking can reduce sheep performance by up to 80 % (Barnes & Dempsey 1992). This is in broad agreement with results of a grazing trial carried out at Athole Research Station (Malherbe 1971). Cattle do not appear to be affected by the presence of residual dead herbage in the veld to the same degree as sheep (Malherbe 1971). It would, however, seem logical to provide cattle with the highest quality feed available, i.e. with the least amounts of residual dead herbage present.

1.2.3.2 Veld vigour

Results of several local grazing and cutting trials indicate that defoliation of a grass plant throughout the growing season results in a drastic reduction in vigour (Barnes 1989a; 1989b; Moore 1989; Barnes & Dempsey 1992; Peddie *et al.* 1995; Lutge *et al.* 1996). Similar conclusions were reached by Reece *et al.* (1988) after investigating the effects of SDG on grass vigour. These results indicate that control of defoliation patterns in an attempt to optimise grass productivity based on management of carbohydrate reserves is not easily obtained. This, together with evidence presented earlier, indicates that grazing procedure is of relatively minor importance and should therefore not form the basis of grazing management recommendations. The intensity, frequency (Barnes 1989a; 1989b; Moore 1989) and time of initial defoliation (Barnes 1992) affect the degree of vigour reduction. The provision of material preferred by sheep (short leafy grass free of residual dead herbage) requires early, heavy stocking after a spring burn and will result in a greater decline in vigour than grazing by cattle which graze more uniformly and less intensively than sheep. This is reinforced by empirical evidence showing that sheep have a greater potential to cause veld degradation than cattle (O'Reagain & Turner 1992). It must be realised, however, that any defoliation affects grass vigour. Indications are that an extended rest period is required to compensate for vigour reduction (Barnes & Dempsey 1992).

Little or no direct research has been done in South Africa to investigate the need for rest. Also, the type or period of rest and the required frequency of rest necessary under local conditions has not been investigated. Traditionally, rest has been classified as either rest based on animal requirements or on plant requirements (Tainton 1981d).

Rest based on animal requirements includes the periods of absence in rotational grazing systems that allow for the accumulation of sufficient herbage to ensure adequate intake during the following grazing cycle. It also includes longer rest periods for the accumulation of material for conservation (e.g. as foggage) for use during the dormant season or as a drought reserve (Tainton 1981d). Considering results referred to above (Barnes 1989a; 1989b; Moore 1989; Barnes & Dempsey 1992), periods of absence during a rotational grazing procedure do not appear to have a beneficial effect on the restoration of vigour following defoliation.

Rests based on plant requirements are generally considered to be rests designed to benefit the species composition and density, and the plant vigour (Tainton 1981d). Rests are often advocated for seeding purposes when veld is dominated by unpreferred species (e.g. Trollope (1992)). While the role of seeding in sourveld under sheep and cattle grazing conditions is not yet fully understood, it is suggested that unless regular resting is practised, a depletion of the supply of seed of preferred grasses and an increase in the seed supply of unpreferred grasses might result. A once-off seeding rest may then favour the unpreferred grasses with more available seed.

The detrimental effects of grazing on plant vigour have been highlighted previously. These effects are thought to play a major role in the loss of vigour of the preferred species and their eventual replacement by less preferred species whose vigour is unaffected or stimulated by grazing (due to reduced competition by less vigorous preferred species). It appears that the vigour of preferred species will decline even during one season of grazing, irrespective of grazing procedure, and it can safely be inferred that grazing for two or more seasons consecutively will have at least an additive debilitating effect on vigour. For this reason it is felt that the major reason for resting veld should be to compensate for the loss of vigour caused by grazing. Results from the study by Barnes & Dempsey (1992) indicate that a full growing season rest is adequate for the required vigour recovery. It is thus suggested that, without additional empirical evidence, a full growing season rest be provided to cater for vigour recovery. In addition, regular full season's rests may contribute towards maintaining an adequate supply of seed of the preferred grasses.

1.2.3.3 Utilisation of rested veld in fodder-flows

The full season rest thus required in a grazing system could provide accumulated material (foggage) at the end of the growing season. This can be successfully utilised in many sourveld regions for certain classes of animals provided with the necessary protein supplementation. It has been demonstrated at Nooitgedacht Agricultural Development Centre that it is feasible to winter pregnant ewes successfully on such rested veld with suitable protein supplement at relatively low cost (Moore & Müller 1994). The development of cattle and sheep farming systems at Athole Research Station based almost entirely on veld as a source of both summer and winter feed has further illustrated this principle (Anon. 1997).

The utilisation of sourveld during the dormant season should not have any detrimental effect on veld condition provided winter grazing commences after killing frosts and is terminated before spring growth (du Toit & Ingpen 1970; Rethman *et al.* 1971).

1.2.4 Recommendations based on above perspective

The incorporation of the principles outlined above into grazing management strategies was based firstly on the provision of adequate rests (in the form of full growing season rests). This was to enable preferred plants to regain vigour after a season or seasons of defoliation and thus provide for sustainable production of preferred feed, as well as maintenance or improvement of veld condition. Secondly, provision was made for satisfactory animal performance and improved fodder-flow (on an economic basis). Thirdly, recommendations were based on easily understood principles, were cheap (non-capital intensive) and easy to implement.

Four possible scenarios were envisaged, ranging from sheep production to cattle production with two broad combinations of varying sheep : cattle ratios between.

1.2.4.1 Two block strategy

It has for many years been advocated that sheep should be stocked together with cattle in a ratio not exceeding 6:1, to prevent veld degradation and facilitate satisfactory sheep performance (Transvaal Region 1984). Little or no effort has been put into developing grazing management recommendations suitable for sheep alone. There are, however, many sourveld livestock farmers who farm with sheep alone and many that have sheep to cattle ratios wider than 6:1. This is largely due to economic reasons, as sheep production is much more profitable than beef production locally (Horn 1993).

It seems that a rational approach to management of veld for sheep production would be to apply practices that favour sheep performance, i.e. burning combined with early stocking, in one season. As mentioned earlier, any grazing detrimentally affects grass vigour, whatever the system or procedure applied. A long-term rest is necessary to compensate for this vigour loss (Barnes & Dempsey 1992), and this can be accomplished by resting in the next season.

Such a system would logically involve dividing a farm into two blocks of comparable grazing capacity. There should normally be several paddocks within each block after separation of veld types. During year one, block one is burned during the late dormant season to remove residual dead herbage if necessary. The block is grazed for the duration of the growing season in a manner to facilitate satisfactory animal performance. During the dormant season, block two is available for grazing. During year two, block two is burnt during the late dormant season and is grazed during the growing season, while block one rests in preparation for winter utilisation (Table 1.1).

Obviously, careful fodder-flow planning is required to utilise the veld optimally with a suitable class of animals at the correct time of year. For example, while rested veld with a protein supplement may be sufficient for wintering dry stock, it will be unsuitable for young, growing livestock. Also, the period between the burning of the rested veld and its subsequent utilisation can be a critical period. Staggered burning can partially overcome this problem, but alternative cheap feed sources are usually necessary for this period. The incorporation of rested veld reduces the need for alternative feed sources to a minimum.

1.2.4.2 Three block strategy

Sheep and cattle are often stocked together in ratios wider than 6:1. A realistic management strategy for this scenario would be to divide a farm into three blocks of comparable grazing capacity. During year one, block one is burnt if necessary and grazed by sheep during the growing season in a manner to facilitate satisfactory sheep production. Cattle graze block two (which was grazed by sheep during the previous season). The defoliation of the preferred grasses in block two will be less severe than the defoliation by sheep in the previous season, as cattle graze more uniformly (Hardy 1994), and there are fewer large stock units of cattle relative to sheep in this scenario. Block three (which was grazed by cattle in the previous season) rests during the growing season in preparation for winter grazing and a late dormant season burn if necessary. This cycle is repeated every three years (Table 1.2). Although untested, it is felt that the lower sheep numbers (due to the cattle component) relative to a situation where sheep graze alone allows the resting frequency to be relaxed from every second to every third year.

It may be desirable to graze sheep and cattle together on the same block, and this can be accommodated, although currently it would seem desirable not to graze a specific block with sheep for more than one season without resting.

This strategy was designed for a scenario with more than six sheep per head of cattle, but is also suitable for lower ratios of sheep to cattle or cattle alone.

1.2.4.3 Four block strategy

Producers with sheep and cattle in a ratio of less than 6:1 could divide the farm or unit into four blocks of equivalent grazing capacity.

During year one, block one is burnt during the late dormant season if necessary and grazed by sheep, again in a manner that will ensure satisfactory sheep performance. Cattle now graze block two and three, as there are relatively more cattle in this scenario. Block four is rested in preparation for winter utilisation. This cycle is repeated every four years (Table 1.3).

Again, it may be desirable to graze sheep and cattle together on the same block, and this can be accommodated, although again it would seem desirable not to graze a specific block with sheep for more than one season without resting.

Careful fodder-flow planning is necessary for optimal utilisation of the veld. In the absence of supporting evidence, it is suggested that in such a scenario with relatively few or no sheep, at least one quarter of the veld should be rested annually. It may be necessary to rest more than one quarter of the veld to provide sufficient winter-feed. In the crop growing areas of the sourveld, many farmers winter sheep on crop residues, and, in that case, it is suggested that the rested veld be used primarily for cattle as well as for sheep during the periods before crops are harvested and after crop residues are depleted.

1.2.4.4 Cattle alone

Cattle are intrinsically more suited than sheep to the utilisation of sourveld. However, even if veld is stocked at the correct stocking rate with cattle, periodic full season rests are necessary. It has been shown that even lenient and infrequent defoliation reduces the vigour of the preferred grasses (Moore 1989). In the absence of empirical data, it seems that a rest at least every four years is indicated to improve vigour of the preferred grasses.

As a basis, enough veld should be rested to provide the required amount of winter grazing, with the constraint that at least one quarter of the veld should be rested annually on a rotational basis.

Any of the above strategies can be used for cattle alone. Cattle with the highest quality feed requirement will obviously replace the sheep in the scenarios above.

1.2.5 Grazing procedure within blocks - the indicator paddock approach

Recent research indicates that multi-paddock rotational grazing systems offer little advantage over few paddock systems in terms of manipulating defoliation patterns and the periods "out" in rotational grazing systems are usually too short to allow for vigour recovery. It makes sense then to manage veld within a block that is being grazed in a manner flexible enough to take advantage of seasonal fluctuations in production, and in a manner to facilitate good animal performance (keeping grass short and leafy).

The so-called indicator paddock system is one method of doing this. In principle one concentrates on one or more "indicator" paddocks during the growing season. These paddocks are then well grazed throughout the season. Other paddocks within the block are only grazed when necessary, and animals are returned to indicator paddocks as soon as they are again ready for grazing. In this way, quality is maintained on the indicator paddocks by keeping them short and leafy. Also, in years of good rainfall, some paddocks in the grazing block may not be grazed at all or may only be grazed at a low frequency, resulting in more than the recommended area being rested. In years of poor rainfall, if all feed in the grazing block has been used, it may be necessary to move into a block designated for resting, resulting in less than the recommended area being rested. This should serve as a timely warning that there will be a shortage of winter feed, and decisions regarding stock numbers or alternative feeding strategies can be taken timeously. In the long term, if the stocking rate is correct, the correct amount of veld should be rested. The indicator paddock approach is based on the flexible system of veld management first published by Venter & Drewes (1969).

These strategies were based on research results available at the time (before the present study was initiated) and were designed to cover most scenarios in sheep and cattle farming situations in sourveld. They have been applied successfully on research farms and commercial farms. However, they are by no means the last word in current veld management systems. For example, the "five cell system" as applied by Neil Murray, a farmer from Kokstad (Murray 1995), includes most of the principles outlined above, but also formally incorporates a drought reserve, and veld in each cell rests for two consecutive years in a five year cycle. The "five cell system" is a further development of the Venter & Drewes (1969) proposals.

The strategies outlined above offer the following advantages over traditional veld management recommendations:

- Provision is made for maintenance of vigour.
- Sheep grazing frequency is reduced i.e. annual grazing by sheep no longer takes place.
- Provision is made for facilitating satisfactory sheep performance.
- Provision is made for winter grazing of rested veld, which has a beneficial effect on fodder-flow and economics.

1.3 Objectives

This approach to management of sourveld outlined above represented a marked change from traditional veld management recommendations. While the underlying principles were considered sound, it was considered necessary to initiate further investigations, in particular with regard to the effects of time of stocking in spring and stocking rate on both animal performance and veld vigour and condition. It was considered essential to quantify the differences between the effects of sheep and cattle grazing on veld vigour. Also, information regarding the effects of type and frequency of resting on veld vigour was considered important.

Consequently, two trials were laid out with the aim of identifying the main management factors influencing animal performance and veld vigour, thus building up a better understanding of veld dynamics, and improving veld management recommendations. The emphasis throughout was to develop scientifically sound, practical veld management guidelines aimed at maintaining or improving veld vigour and condition, while making provision for economic livestock production, by providing good quality veld of the required quantity suitable for local livestock production systems.

1.3.1 Trial 1: Interactive effects of stocking rate and period of deferment before stocking spring-burnt sourveld on sheep performance, veld productivity and proportional species composition

There were four main objectives in this trial:

1. to quantify the effects of the interaction between stocking rates and time of stocking spring-burnt sourveld on the performance of sheep,
2. to determine the grazing pattern of sheep by monitoring the changes in herbage mass of each grass species over the grazing season,
3. to determine the effects on veld vigour by quantifying the residual effects on the productivity of the veld as a whole as well as of individual grass species in the year following treatment application, and

4. to determine the effects of the treatments on the proportional species composition of the veld.

1.3.2 Trial 2: The influence of various types and frequencies of rest on the production and condition of sourveld grazed by sheep or cattle

The main objectives in this trial were to establish the effects of different types and frequencies of rests on veld production and proportional species composition of sour grassveld grazed by sheep or cattle with various combinations of resting treatments.

1.4 Approach

The approach followed in this study was to identify the most important veld related factors influenced by management that play a role in both veld condition and livestock performance, and investigate the most important livestock management factors impacting these. The livestock factors involved livestock type (sheep and cattle), livestock numbers (stocking rate) and livestock movement (time of stocking and various resting treatments).

The idea in this study was to adopt a top-down approach in an attempt to gain an understanding of the main factors which are important in determining impact on veld and livestock production.

Table 1.1 Schematic outline of two block grazing strategy.

	Block 1	Block 2
Year 1 Growing season	Burn Graze	Rest
Year 1 Dormant season		Graze
Year 2 Growing season	Rest	Burn Graze
Year 2 Dormant season	Graze	

Table 1.2 Schematic outline of three block strategy.

	Block 1	Block 2	Block 3
Year 1 Growing season	Burn Sheep	Cattle	Rest
Year 1 Dormant season			Graze
Year 2 Growing season	Cattle	Rest	Burn Sheep
Year 2 Dormant season		Graze	
Year 3 Growing season	Rest	Burn Sheep	Cattle
Year 3 Dormant season	Graze		

Table 1.3 Schematic outline of four block strategy.

	Block 1	Block 2	Block 3	Block 4
Year 1 Growing season	Burn Sheep	Cattle	Cattle	Rest
Year 1 Dormant season				Graze
Year 2 Growing season	Cattle	Cattle	Rest	Burn Sheep
Year 2 Dormant season			Graze	
Year 3 Growing season	Cattle	Rest	Burn Sheep	Cattle
Year 3 Dormant season		Graze		
Year 4 Growing season	Rest	Burn Sheep	Cattle	Cattle
Year 4 Dormant season	Graze			

CHAPTER 2

TRIAL 1: INTERACTIVE EFFECTS OF STOCKING RATE AND PERIOD OF DEFERMENT BEFORE STOCKING SPRING-BURNT SOURVELD, ON SHEEP PERFORMANCE, VELD PRODUCTIVITY AND PROPORTIONAL SPECIES COMPOSITION

2.1 Experimental procedure

The first trial was laid out at Athole Research Station and was designed to investigate the impact of livestock numbers and movement on sustainable utilisation of sourveld.

2.1.1 Experimental site

The study was conducted at Athole Research Station about 60 km east of Ermelo (26°32'E; 29°58'S), situated within the Piet Retief Sourveld (Acocks 1975). Athole is located at an altitude of 1620 m above sea level. The soils on the site were classified as predominantly of the Bainsvlei and Avalon forms (MacVicar *et al.* 1977). The Bainsvlei form comprises an orthic A horizon over a red apedal B over a soft plinthic B horizon. The Avalon form comprises an orthic A horizon over a yellow-brown apedal B over a soft plinthic B horizon. The only difference between the two soil forms on the trial site was a colour difference in the apedal B horizon. Effective soil depths varied from 350 to 550 mm. The climate is temperate with high rainfall, warm summers and cool winters. The mean annual rainfall is 992 mm (45 year record) (Erasmus 1992) with the rainfall concentrated in the summer months. Rainfall distribution and the rainfall for the trial period are shown in Table 2.1. Mean maximum temperatures in summer and winter are 23.7 °C and 13.0 °C respectively (Koch undated (a)). The mean minimum temperatures are 17.0 °C and 3.1 °C respectively (Koch undated (b)). The maximum and minimum temperature details for the trial period are shown in Tables 2.2 and 2.3 respectively.

The experimental site comprises about 16 ha of reasonably uniform veld that had not been used for experimental work at least eight years prior to the start of this trial. The site had been grazed sporadically and was burnt in alternate years in the late dormant season during that period. The site comprised 16 paddocks of 1.0 ha each. These were divided into two blocks of 8 paddocks each (Figure 2.1). During the first year it became obvious that the species composition and consequent productivity composition in particularly treatments E 16 and E 7 (Block 1) were different enough to warrant an adjustment of paddocks for the remainder of the trial (Figure 2.2). The proportion of *Rendlia altera* in those two treatments was initially somewhat higher than in the other treatments.

2.1.2 Procedure

The trial was initiated at the beginning of the 1992/93 season. Treatments involving time of stocking in spring and stocking rate were applied in factorial combination on spring-burnt veld. Animal performance was determined, and changes in the quantity and quality of herbage on offer, as well as the quality of herbage selected by the animals, was measured in the different treatments at intervals during the growing season.

The procedure used in the current study followed that of Barnes & Dempsey (1992). The experimental area was divided into two blocks, with each block being grazed in alternate years. The residual effects of the grazing treatments on the production of the grass species present were determined during the rest year. A technique involving dry-weight-rank (t'Mannetje & Haydock 1963) using the original weights for the ranks but modified by Jones & Hargreaves (1979) to include cumulative ranking and by Barnes *et al.* (1982) to include the use of shared ranks, in conjunction with herbage yield determinations, was successfully used for this purpose. The same technique was used to determine the residual effects of the treatments in the present trial. In addition a slightly modified procedure was used to establish the changes during the season in the amounts of herbage of the grass species present. (See Appendix 1)

Accordingly each of the two blocks on the experimental area was treated as follows in alternate seasons starting in the 1992/93 season:

Block 1 (1st season)

- The whole block was burnt late in the dormant season using a cool fire (air temperature below 20 °C and relative humidity above 50 % (Trollope 1989)) in order to remove residual dead herbage.
- Fifty circular exclosure cages, one metre in diameter, were placed in each of the eight paddocks in a regular pattern so as to obtain a representative sample of the veld in each paddock.
- The following grazing treatments were applied using weaner Merino lambs, with an initial mass of about 30 kg, using one continuously grazed paddock for each treatment:
  - Time of stocking (2): Sheep were put on the veld when it was judged that there was just enough material to carry the stock (E) (usually mid-October); and three weeks later (L).
  - Stocking rate (4): 16, 13, 10 and 7 sheep per 1.0 ha paddock.
  - Immediately before stocking the paddocks in spring, a dry-weight-rank botanical analysis (Appendix 1) was conducted using 200 quadrats (300 mm square) per paddock placed at regular intervals so as to obtain a representative sample of the veld. The selection of sampling intensity and quadrat size was based on research by Barnes, Odendaal & Beukes (1982). Concurrently, the dry matter (DM) yield of the herbage in each paddock was determined (kg DM ha^{-1}) by means of a double sampling technique (as described by t'Mannetje (1978)) in which the yield of the above 200 quadrats per paddock was estimated (Appendix 1). Every tenth quadrat was harvested at a height of 20 mm above ground or tuft level and regression analysis was carried out to determine the relation between the estimates and the actual yields.
  - Crude protein (CP) and in vitro digestible organic matter (IVDOM) contents of the herbage on offer was determined (using the herbage from the previously harvested quadrats) as well as of samples collected from oesophageally

fistulated sheep at the time of stocking (two per treatment) from all treatments. These yield and quality determinations were carried out at two weekly intervals until the end of December and then monthly until the end of the grazing season.

- Unstarved lamb livemass was recorded at the start and end of each season, and at approximately 14-day intervals during the grazing season.

Block 2 (1st season)

The whole block was rested for the season, as the treatments were applied to the two blocks in alternate seasons.

Block 1 (2nd season)

- In the late dormant season (August) the residual herbage within the exclosure cages (growth from the previous season) was cut to a height of 20 mm above ground or tuft level and the cut material was removed. Equivalent areas adjacent to the cages were prepared in the same way. The exclosure cages were then removed and the paired plots marked with pegs.
- A dry-weight-rank analysis was conducted on the prepared plots (using four 300 mm square quadrats per plot totalling 400 quadrats per paddock) during mid-December, to determine the residual effects of the treatments in the 1st season on grass species production during the second season, compared with the adjacent ungrazed control plots.
- The whole block was burnt late in the dormant season in preparation for grazing.

Block 2 (2nd season)

Treat as under Block 1 (1st season) above.

The treatments were alternated between blocks in the same manner for the duration of the trial. The trial continued beyond the four years used for the purpose of this study.

2.1.3 Supplementary measurements

Proportional species composition of each paddock was determined (using the nearest-plant point method with a wheel point apparatus to locate 300 points systematically per paddock) during the first season (1992/93) and during the 1996/97 season.

Table 2.1 Mean annual rainfall and rainfall for the trial period and the preceding season for Trial 1 at Athole Research Station (mm)

	MEAN	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
JUL	13.0	0.3	0.4	0.0	0.0	3.7	36.5
AUG	17.0	5.5	13.4	8.7	2.0	10.5	13.4
SEP	48.0	40.3	23.9	9.8	25.7	7.9	0.0
OCT	104.0	41.1	86.1	84.7	115.5	108.9	174.6
NOV	145.0	126.2	67.9	160.3	103.8	100.1	55.6
DEC	161.0	85.2	245.4	154.0	131.9	298.0	128.8
JAN	169.0	106.7	132.4	136.9	139.3	217.3	215.7
FEB	147.0	56.8	101.3	80.8	52.8	245.0	155.0
MAR	97.0	32.6	149.1	98.8	113.2	189.0	145.0
APR	59.0	14.0	75.3	9.9	44.3	60.7	42.5
MAY	19.0	0.0	7.4	3.6	1.0	50.1	12.5
JUN	13.0	1.5	0.2	0.0	5.1	0.0	22.5
TOTAL	992.0	510.2	902.8	747.5	728.5	1291.2	1002.1

Table 2.2 Mean annual maximum temperatures and maximum temperatures for the trial period and the preceding season for Trial 1 at Athole Research Station (°C)

	MEAN	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
JUL	17.3	18.5	19.3	18.8	17.7	18.8	15.0
AUG	19.7	20.9	18.8	20.3	19.1	21.4	18.4
SEP	22.0	22.9	25.3	25.7	24.3	25.3	24.5
OCT	22.9	24.2	24.9	22.6	21.4	23.9	23.9
NOV	23.0	24.2	24.2	22.3	24.5	23.1	23.7
DEC	23.9	24.3	26.2	24.7	24.2	22.3	24.4
JAN	23.7	26.7	25.2	23.5	25.3	23.4	23.6
FEB	23.4	27.2	22.5	22.7	25.7	23.1	25.0
MAR	22.8	25.6	22.4	23.4	22.9	22.9	22.3
APR	21.5	25.2	22.2	21.5	21.4	20.0	22.1
MAY	19.3	22.1	21.2	21.0	19.0	18.3	17.9
JUN	17.0	18.8	17.8	18.2	18.9	18.5	19.0

Table 2.3 Mean annual minimum temperatures and minimum temperatures for the trial period and the preceding season for Athole Research Station (°C)

	MEAN	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
JUL	3.1	3.7	4.0	3.1	1.0	4.6	2.6
AUG	5.0	5.1	4.2	3.7	2.8	6.8	5.2
SEP	7.8	9.4	10.3	8.0	7.4	9.7	9.3
OCT	9.9	10.8	10.9	9.7	8.2	11.1	11.4
NOV	11.4	11.9	11.2	10.9	12.1	12.1	12.1
DEC	12.6	12.2	13.8	13.5	11.6	12.4	13.0
JAN	13.0	13.7	12.8	12.8	13.2	13.9	13.8
FEB	12.9	14.7	12.3	12.5	13.5	13.8	13.8
MAR	12.0	11.6	10.9	11.7	12.6	11.8	13.1
APR	9.6	11.3	9.5	7.3	9.1	8.9	7.8
MAY	6.2	7.0	6.3	4.7	6.4	6.0	5.6
JUN	3.3	4.6	1.8	1.7	4.1	4.5	3.6

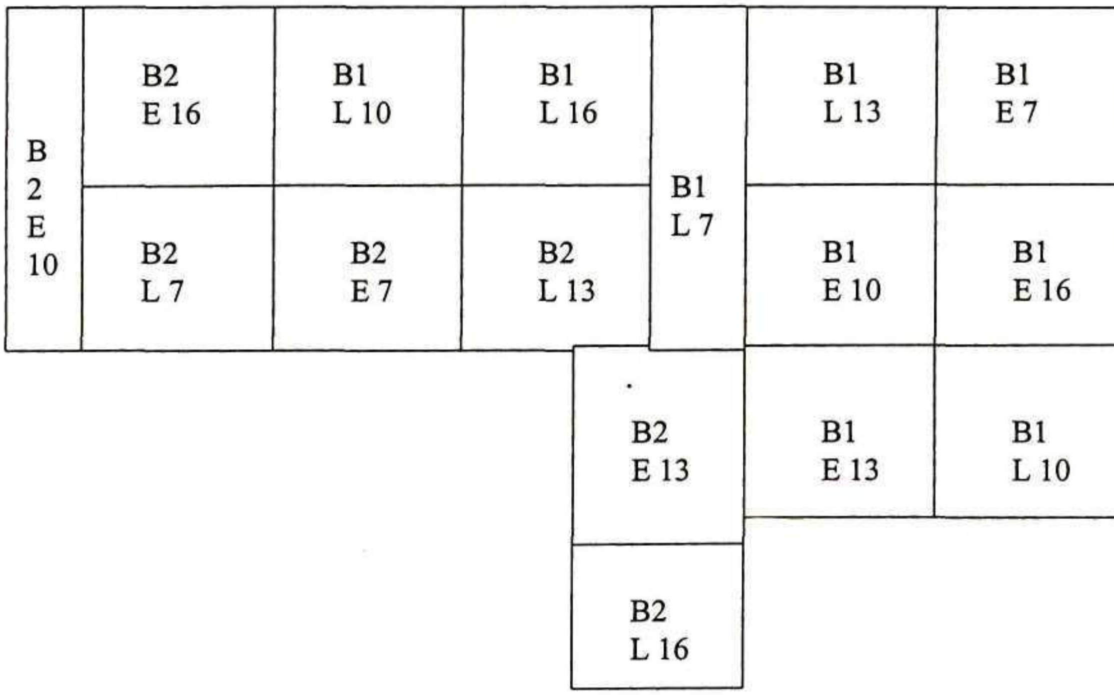


Figure 2.1 Initial layout of Trial 1 according to blocks (B), time of stocking (early - E or late - L) and stocking rate (7, 10, 13 or 16). Each paddock is 1 ha in size. The diagram is not drawn to scale

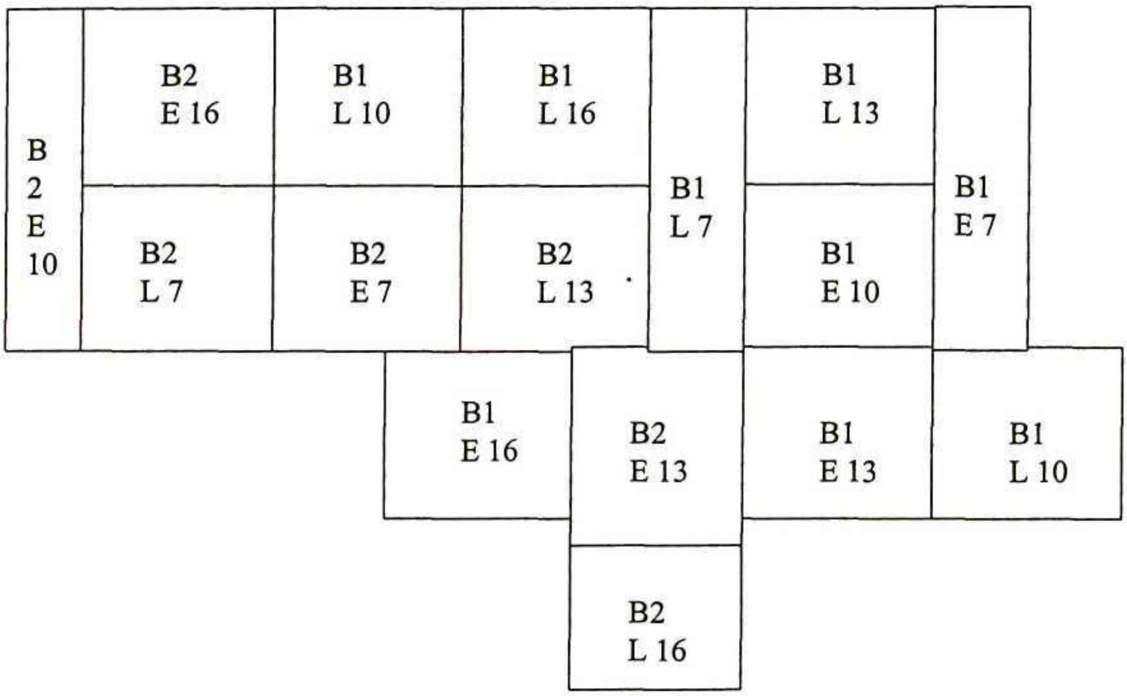


Figure 2.2 Amended layout of Trial 1 according to blocks (B), time of stocking (early - E or late - L) and stocking rate (7, 10, 13 or 16). Each paddock is 1 ha in size. The diagram is not drawn to scale

CHAPTER 3

TRIAL 1.

EFFECTS OF STOCKING RATE AND TIME OF STOCKING ON THE PERFORMANCE OF SHEEP

3.1 Methodology

The trial was conducted according to the procedures set out in chapter 2. Additional details regarding the trial procedures are described in the following sections.

3.1.1 Allocation of sheep to treatments

Merino lambs born during April prior to each season were used. Sheep were weighed before commencement of the trial each season and allocated to treatments in a manner to ensure uniformity of groups. Allocation of sheep to treatments was done the day before stocking the early treatment. A "marker" group of seven sheep were selected to be as close to equal in mass as possible for both the early and late treatments. Extra sheep were placed in the heavier stocking rate treatments to make up the numbers. The extra sheep were also selected to maintain the mean mass of each group as close to the mean of the marker group as possible. The marker group of seven uniform sheep was used for determining sheep performance. The whole groups for each treatment were used for evaluating grazing impact. The initial mass of the groups differed slightly from year to year, and the late time of stocking treatment groups were always heavier at stocking than the early treatment (Table 3.1). This was unavoidable, as the late groups grazed burnt veld comparable to the veld on the trial site, and gained mass during the three-week interval between early and late stocking. The sheep were removed from the veld near the end of April in each season unless feed shortages shortened the season.

3.1.2 Procedures with respect to stolen or sick sheep

Stock theft occurred at a low intensity throughout the trial and increased in magnitude during the third and fourth season. On rare occasions individual sheep were removed from the trial because of health problems. A group of replacement sheep from the same origin as the trial sheep was kept on adjacent, similar veld. Where a sheep from a marker group was missing, one of the extra sheep in the treatment group was allocated to the marker group, and the replacement sheep allocated to the non-marker group. The replacement marker sheep was then used as a marker for the duration of the season, not just from the replacement date. In one instance (1995/96 season late time of stocking) a replacement had to be made in the lightest stocking rate group. The marker group thus had to be reduced to six sheep.

3.1.3 Determination of sheep performance

All sheep were weighed approximately fortnightly using an electronic scale. The sheep were weighed at the same time of day on each occasion, without overnight starving.

3.1.4 Data analysis

Data were analysed using a procedure to fit polynomial curves to the sheep mass data. The curve fitting was done to smooth the data and thus minimise the impact of any single data point. It also allowed for comparison of curves. Care was taken in fitting the curves not to "over-fit" and end up with a biologically meaningless mathematical function. In all cases functions ranging from linear to quartic curves were fitted to all the data from all treatments over all seasons. All data were examined concurrently and curves were fitted in a forward stepwise manner to prevent "over-fitting". The coefficients of determination and residual mean square were examined in each case, along with a plot of the residuals to select the most suitable polynomial. The aim was to find the lowest order polynomial that adequately described the data in a satisfactory manner, both biologically and mathematically. A summary of the polynomial curves fitted to the sheep mass data is presented in Table 3.2.

The sheep masses (mean mass of each sheep during the season) were converted to metabolic mass (Mentis 1981; Meissner *et al.* 1983; McDonald *et al.* 1988) and used to calculate large stock units (LSU) (Trollope *et al.* 1990) grazing days as follows:

1. the mean mass of each sheep was raised to the power 0.75;
2. this was divided by $450^{0.75}$ to give LSU;
3. LSU's were added per treatment.
4. LSU grazing days were calculated by multiplying the treatment LSU's by the number of grazing days.

Although using the small stock unit (SSU) (Trollope *et al.* 1990) may appear more appropriate for a sheep trial, the LSU is more widely used. The stocking density in terms of LSU per hectare, the days grazed and the consequent LSU grazing days are shown in Table 3.3.

The initial dates of stocking, as well as the periods of deferment between the early and late times of stocking and the total season length varied from season to season (Table 3.3 and 3.4). This implies that the treatments cannot, strictly speaking, be considered as comparable between seasons. This, along with the lack of treatment replication, precludes the calculation of statistical criteria for comparing mass gains per sheep or per ha using techniques such as analysis of variance. Interpretation of the results depends on the inspection of trends in mean mass change between treatments, as well as examination of the mass change patterns within seasons.

It was necessary to de-stock certain treatments early in certain years. The heavy stocking rate (16 sheep ha^{-1}), both early and late treatments during the first season, as well as the early heavy stocking rate during the second season were de-stocked early. The sheep were removed once the mass gain for the season dropped close to zero. The mass gains for those treatments were thus taken as zero.

3.1.5 Amendment of trial layout

As each season was treated separately, the amendment to the layout after the first season (mentioned in Chapter 2) did not have any impact on the validity of the sheep performance data. The season long rest between grazing cycles was incorporated in the design in an attempt to negate any carry over of treatment effect on livestock performance in the short term.

3.2 Results

The effects of the treatments on sheep performance are quantified and discussed briefly in this chapter. More detailed discussion regarding the impact of quality and quantity variations on sheep performance is found in Chapter 6.

3.2.1 Sheep performance

The sheep performance data are presented in two ways. Firstly, responses to treatments over the four seasons are presented in terms of mass gain per sheep and per ha. Secondly, the patterns of response within seasons are presented for each treatment both as mass changes and as progressive average daily gains during each season.

3.2.1.1 Mass gains per sheep and per hectare

The mean mass gains per sheep were computed from the polynomial curves fitted to the data, and are presented in Table 3.4. As a consequence of the variations in season length between, firstly, the early and late treatments and, secondly, the four seasons under consideration, it is practically impossible to determine objectively a fixed period for comparative purposes between seasons and between the early and late treatments. For the purpose of discussing mass gains each season has thus been treated separately for each of the early and late treatments. The average daily gain (ADG) sheep^{-1} for each season was calculated (Table 3.5). The ADG values were plotted for each treatment along with the corresponding mass gain ha^{-1} (Figure 3.1). The mass gains ha^{-1} for all treatments are presented in Table 3.6.

The patterns of response to time of stocking (Tables 3.4 & 3.5) were consistent for three of the four seasons. Stocking approximately three weeks after the earliest time of stocking resulted in reduced mass gains of 35 %, 46 % and 26 % in the first, third and fourth seasons respectively. For the late time of stocking sheep gained on average 10 % more mass than the early time during the second season.

The patterns of response to stocking rate were consistent for all seasons and times of stocking with the exception of the second season, early time of stocking. The general pattern of response was that of low mass gains at the heaviest stocking rate, greater mass gains at the two intermediate stocking rates and reduced gains at the lowest stocking rate. An exception to this occurred during the 1993/94 season where the highest mass gain for the early time of stocking treatment was obtained with the lightest stocking rate.

It is interesting to note the mean mass gains and ADG's per treatment for the four seasons under consideration (Table 3.4 & 3.5). For both the early and late times of stocking, the highest mass gains occurred at the 10 sheep ha^{-1} stocking rate. The mass gains were higher for the early time of stocking.

The maximum mass gain ha^{-1} occurred at a higher stocking rate than the mass gain $sheep^{-1}$. On average over the four seasons under consideration, the highest mass gain ha^{-1} occurred at the 13 sheep ha^{-1} stocking rate (Table 3.6).

The sheep performance response to stocking rate was not linear, and it was obvious that linear approximations would distort the responses. This precluded testing for differences between times of stocking and between seasons by means of testing the significance of differences in intercepts and slopes between fitted linear functions (e.g. Bransby 1982).

The question of time of stocking has been raised several times (e.g. Barnes & Dempsey 1992; Zacharias 1994). The results obtained in this study are similar to those presented in the other studies mentioned above. In general, the sheep performance (ADG) and the mass gain ha^{-1} are higher for the early time of stocking treatment. The different season length between the early and late time of stocking is a factor that complicates interpretation of the data. In practice, the spring period is usually the most difficult period in the year from a fodder provision perspective. This is particularly true in sourveld regions where quality of veld left over from the previous season is extremely low, and the new season's growth is not yet ready to support livestock. It is thus financially advantageous to move livestock on to the new season's growth as soon as possible. However, the difference in sheep performance and gains ha^{-1} must be considered in the light of the different growing season lengths in the above two studies and the present study. In the present study, the sheep used in both the early and late times of stocking treatment originated from the same group. Those stocked at the late time of stocking were placed on comparable veld for the three-week interim period before being placed on the trial. In order to compare the sheep performance from a different perspective, the mean final sheep mass was tabulated for all treatments (Table 3.7). It is interesting to note that the mean final mass of the late time of stocking treatment was marginally higher than the mean final mass of the early time of stocking group. It is not possible to test the statistical significance of this difference, but the mean difference of 0.39 kg $sheep^{-1}$ over a season is biologically and economically not very important. It still makes practical sense to stock early to avoid either depriving sheep of high quality new growth, or to avoid feeding costly alternatives. However, it seems that no clear advantage in terms of increased sheep mass at the end of the season will materialise.

3.2.1.2 Mass change patterns within seasons

The mass gains for each season cannot be fully understood without examining the mass change patterns within seasons. The polynomial curves fitted to the marker group of seven sheep per treatment were used for the within season comparisons. Examination of the graphical presentations of sheep mass changes within seasons

(Figure 3.2) reveals clear treatment effects, with the effect of season also impacting the pattern of response. During the 1995/96 season, which was the wettest season, the sheep reached peak mass earlier than in any of the other seasons. This was consistent for both the early and late time of stocking. The effect of stocking rate can be seen by the 16 sheep ha^{-1} treatments typically reaching peak mass before the lighter stocking rate treatments.

In order to gain further insight into the patterns of response, the progressive average daily gains (PADG), which represent the average daily gain (ADG) $sheep^{-1}$ day^{-1} from the start of the season to any specified time during the grazing season, were plotted (Figure 3.3). The PADG values were computed from the mass gain curves (Table 3.2). Examination of the PADG curves reveals marked differences between treatments and seasons. Again, the wet 1995/96 season stands out. PADG values were initially relatively high, and dropped quickly to end generally lower than the values in the first three seasons. It appears that in certain treatments, stocking rate had an immediate effect on PADG (e.g. 1992/93 E & L).

3.3 Discussion

The impact of the time of stocking and stocking rate treatments on individual sheep performance and mass gains per ha is clear. It is important to note that light stocking rates can reduce sheep performance relative to heavier stocking rates. The stocking rates for maximum sheep performance and maximum gain per ha differed consistently. It seems that careful manipulation of stocking rates can significantly impact economic returns of sheep farming. The expected advantages of stocking relatively early in spring did not really materialise as the final mass of both early and late treatment groups was similar. It seems that the issue of the effect of time of stocking on sheep performance may have been over-emphasised previously.

Understanding the within-season patterns of response to treatments and seasons possibly opens the way to manipulating seasonal performance by flexible grazing management aimed at controlling the amount and quality of herbage available.

In an experimental design of this type, there is an obvious danger of confounding of paddock and treatment effects. In order to interpret the responses to treatments more fully, it is necessary to examine the sheep performance in the light of quality and quantity factors during the seasons in question. These aspects are examined in Chapters 4 & 5.

Table 3.1 Mean initial mass (kg sheep^{-1}) of each treatment marker group

Treatment	1992/93	1993/94	1994/95	1995/96
E16	27.74	27.54	27.71	30.06
E13	27.63	26.40	29.06	30.10
E10	27.73	26.70	30.91	30.01
E7	27.83	27.49	28.90	30.21
Mean	27.73	27.03	29.15	30.10
L16	30.77	27.71	28.33	31.80
L13	30.09	27.07	28.54	30.81
L10	29.34	29.09	32.66	33.21
L7	29.71	26.95	31.64	32.75
Mean	29.98	27.71	30.29	32.14

Table 3.2 Polynomial models of sheep mass gains (Y) (kg sheep^{-1}) over time (X) for the 1992/93, 1993/94, 1994/95 and 1995/96 seasons (in all cases $P < 0.001$). Regression equations are presented with parameter estimates (constant + days) and percentage variance accounted for (R_a^2)

Season	**Variable**	**E16**	**E13**	**E10**	**E7**
1992/93	Constant	27.94	27.75	27.96	28.07
	Days	0.1084	0.2167	0.1372	0.1886
	Days^2	-0.00166	-0.0055	-0.0029	-0.0031
	Days^3		$6.11\ 10^{-5}$	$2.79\ 10^{-5}$	0.000014
	Days^4		$-2.2\ 10^{-7}$	$-8.1\ 10^{-8}$	
	R_a^2	57.9	92.7	94.1	88.5
		L16	**L13**	**L10**	**L7**
	Constant	30.95	30.24	29.63	29.54
	Days	0.0265	0.0176	0.03879	0.1558
	Days^2	-0.00027	0.000813		-0.00321
	Days^3		$-6.5\ 10^{-6}$		
	R_a^2	17.6	86.2	83.7	55.4
1993/94		**E16**	**E13**	**E10**	**E7**
	Constant	27.563	26.59	26.76	27.34
	Days	0.0695	0.05262	0.0734	0.09126
	Days^2	-0.00032	-0.00012	-0.00022	-0.00023
	R_a^2	83.2	94	91.5	97.7
		L16	**L13**	**L10**	**L7**
	Constant	27.39	26.87	28.93	26.64
	Days	0.08152	0.1176	0.0419	0.1134
	Days^2	-0.00038	-0.00075	0.001401	-0.00106
	Days^3		$1.9\ 10^{-6}$	$1.9\ 10^{-5}$	0.000004
	Days^4			$6.3\ 10^{-8}$	
	R_a^2	95	95.8	97.4	90.6
1994/95		**E16**	**E13**	**E10**	**E7**
	Constant	27.84	29.547	31.23	29.09
	Days	0.1248	0.11109	0.1101	0.1482
	Days^2	-0.00043	-0.00039	-0.00034	-0.00059
	R_a^2	98	98	97.4	97.7
		L16	**L13**	**L10**	**L7**
	Constant	28.35	28.72	32.67	31.39
	Days	0.0646	0.0757	0.1257	0.112
	Days^2	$9.7\ 10^{-5}$	-0.00024	-0.00064	-0.00057
	Days^3	$-2.6\ 10^{-6}$			
	R_a^2	97	98.6	93.4	95.4
1995/96		**E16**	**E13**	**E10**	**E7**
	Constant	30.43	30.797	29.882	30.35
	Days	0.1962	0.1037	0.2246	0.1726
	Days^2	-0.0023	-0.000476	-0.002370	-0.001972
	Days^3	0.0000073		0.0000073	0.0000066
	R_a^2	88.7	84.2	91	53.5
		L16	**L13**	**L10**	**L7**
	Constant	32.206	31.496	34.013	32.267
	Days	0.2272	0.1047	0.2447	0.2451
	Days^2	-0.003781	-0.001388	-0.002967	-0.00424
	Days^3	0.0000163	0.0000057	0.0000101	0.0000195
	R_a^2	81.5	54.1	87.7	52.4

Table 3.3 Stocking density for each treatment during the first four years expressed as LSU per hectare, the number of days grazed and LSU grazing days ha^{-1}

Year	Early Treat.	LSU ha^{-1}	Days grazed	LSU grazing days ha^{-1}	Late Treat.	LSU ha^{-1}	Days grazed	LSU grazing days ha^{-1}
1	E16 *	2.1	70	147.6	L16 *	2.2	99	239.7
	E13	1.8	132	234.8	L13	1.8	111	201.7
	E10	1.4	132	178.6	L10	1.4	111	154.0
	E7	1.0	132	125.6	L7	1.0	111	106.0
2	E16 *	2.2	161	347.2	L16	2.1	160	343.2
	E13	1.8	181	320.9	L13	1.8	160	291.3
	E10	1.4	181	249.2	L10	1.4	160	227.5
	E7	1.0	181	179.5	L7	0.9	160	150.3
3	E16	2.0	169	345.0	L16	2.0	148	293.0
	E13	1.7	169	291.3	L13	1.7	148	256.2
	E10	1.4	169	243.8	L10	1.4	148	213.3
	E7	1.1	169	178.7	L7	1.0	148	155.1
4	E16	2.0	154	314.9	L16	2.0	132	267.4
	E13	1.7	154	270.9	L13	1.7	132	225.6
	E10	1.4	154	212.3	L10	1.4	132	191.8
	E7	1.1	154	143.5	L7	1.0	132	127.3

* Livestock removed early

Table 3.4 Sheep mass gains (kg sheep^{-1}) from the time of stocking until the end of the season for each treatment during the first four seasons

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	E (13/10/92)	3.29	5.94	6.51	0.00	3.94
	L (3/11/92)	3.04	4.31	3.08	0.00	2.61
1993/94	E (19/10/93)	8.89	6.19	5.70	0.00	5.20
	L (9/11/93)	7.29	8.08	7.47	3.27	6.53
1994/95	E (25/10/94)	8.20	8.82	7.54	8.82	8.35
	L (15/11/94)	4.16	4.60	6.00	3.26	4.51
1995/96	E (24/10/95)	3.95	5.06	4.63	2.34	4.00
	L (16/11/95)	3.47	3.86	2.78	1.68	2.95
Mean E		6.08	6.50	6.10	2.79	5.37
Mean L		4.49	5.21	4.83	2.05	4.15
Mean		5.29	5.86	5.46	2.40	4.76

Table 3.5 Average daily gain (ADG) (g sheep^{-1}) from the time of stocking until the end of the season for all treatments during the first four seasons

Season	Time of stocking	Stocking rate 7	10	13	16	Mean
1992/93	E (13/10/92)	25	45	49	0	30
	L (3/11/92)	27	39	28	0	24
1993/94	E (19/10/93)	49	34	31	0	29
	L (9/11/93)	46	51	47	20	41
1994/95	E (25/10/94)	49	52	45	52	50
	L (15/11/94)	28	31	41	22	31
1995/96	E (24/10/95)	26	33	30	15	26
	L (16/11/95)	26	29	21	13	22
Mean E		37	41	39	17	34
Mean L		32	38	34	14	30
Mean		35	39	37	15	32

Table 3.6 Mean mass gains ha^{-1} (kg) for all treatments during the first four seasons

Season	Time of stocking	Stocking rate 7	10	13	16	Mean
1992/93	E (13/10/92)	23.03	59.40	84.63	0.00	41.77
	L (3/11/92)	21.28	43.10	40.04	0.00	26.12
1993/94	E (19/10/93)	62.23	61.90	74.00	0.00	49.53
	L (9/11/93)	51.03	80.80	97.11	52.32	70.32
1994/95	E (25/10/94)	57.40	88.20	98.02	141.12	96.19
	L (15/11/94)	29.12	46.00	78.00	52.16	51.32
1995/96	E (24/10/95)	27.65	50.60	60.19	37.44	43.97
	L (16/11/95)	24.29	38.60	36.14	26.88	31.48
Mean E		42.58	65.01	79.21	44.64	57.86
Mean L		31.43	52.13	62.82	32.84	44.81
Mean		37.01	58.57	71.02	38.74	51.34

Table 3.7 Final sheep mass (kg $sheep^{-1}$) at the end of each of the first four seasons

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	E (13/10/92)	31.96	33.90	34.26	27.38	31.88
	L (3/11/92)	32.58	33.94	33.32	30.94	32.70
1993/94	E (19/10/93)	36.23	32.95	32.29	30.39	32.97
	L (9/11/93)	33.93	37.01	34.34	30.66	33.99
1994/95	E (25/10/94)	36.19	37.48	35.39	34.48	35.89
	L (15/11/94)	35.76	37.54	32.80	31.93	34.51
1995/96	E (24/10/95)	34.30	34.94	35.43	32.77	34.36
	L (16/11/95)	35.74	37.84	34.28	33.89	35.44
Mean E		34.67	34.82	34.34	31.26	33.77
Mean L		34.50	36.58	33.69	31.86	34.16
Mean		34.56	35.70	34.02	31.56	33.97

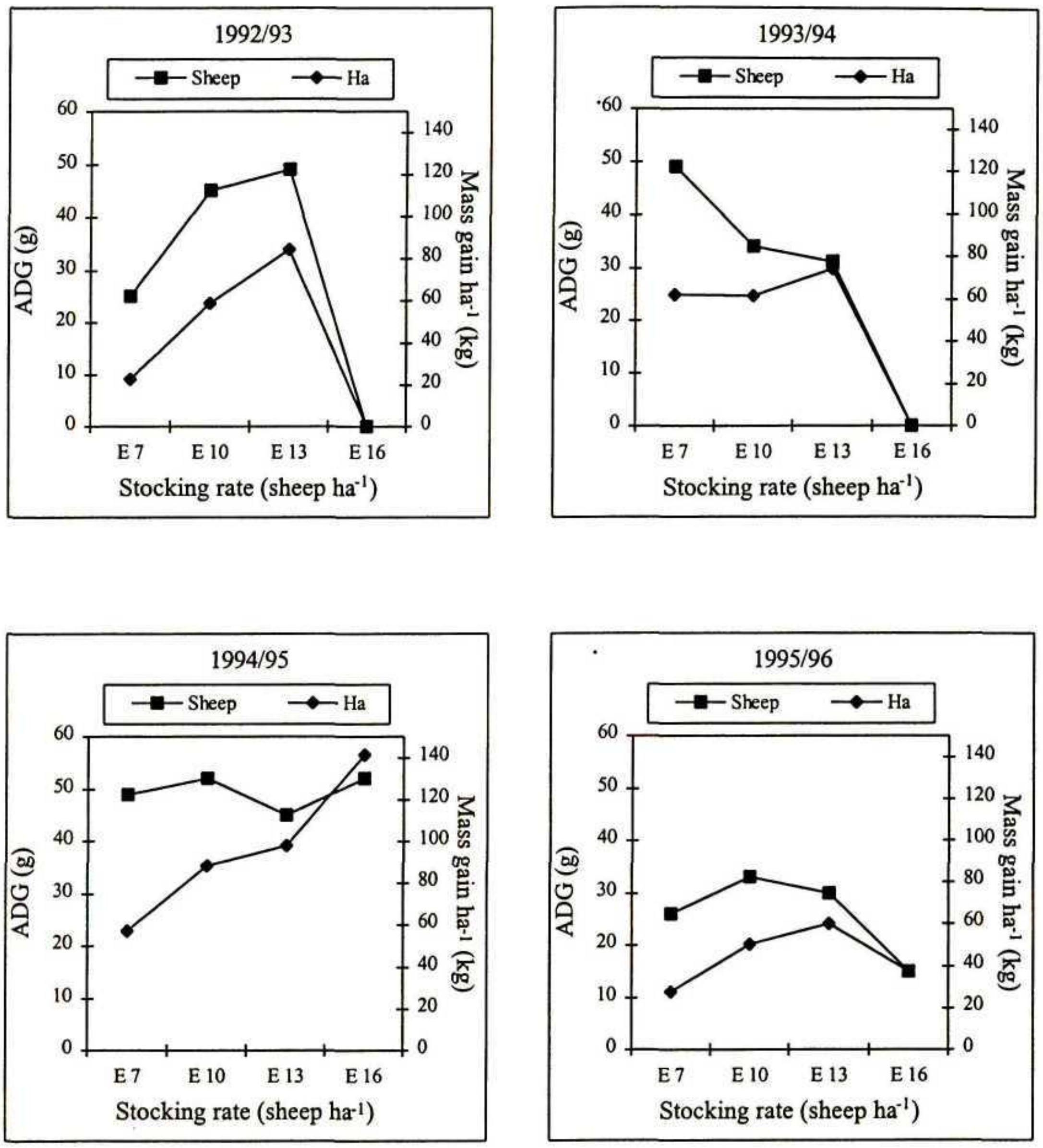


Figure 3.1 (a) Average daily gain (ADG) (g) and gain ha^{-1} (kg) for the early time of stocking treatments during the first four seasons

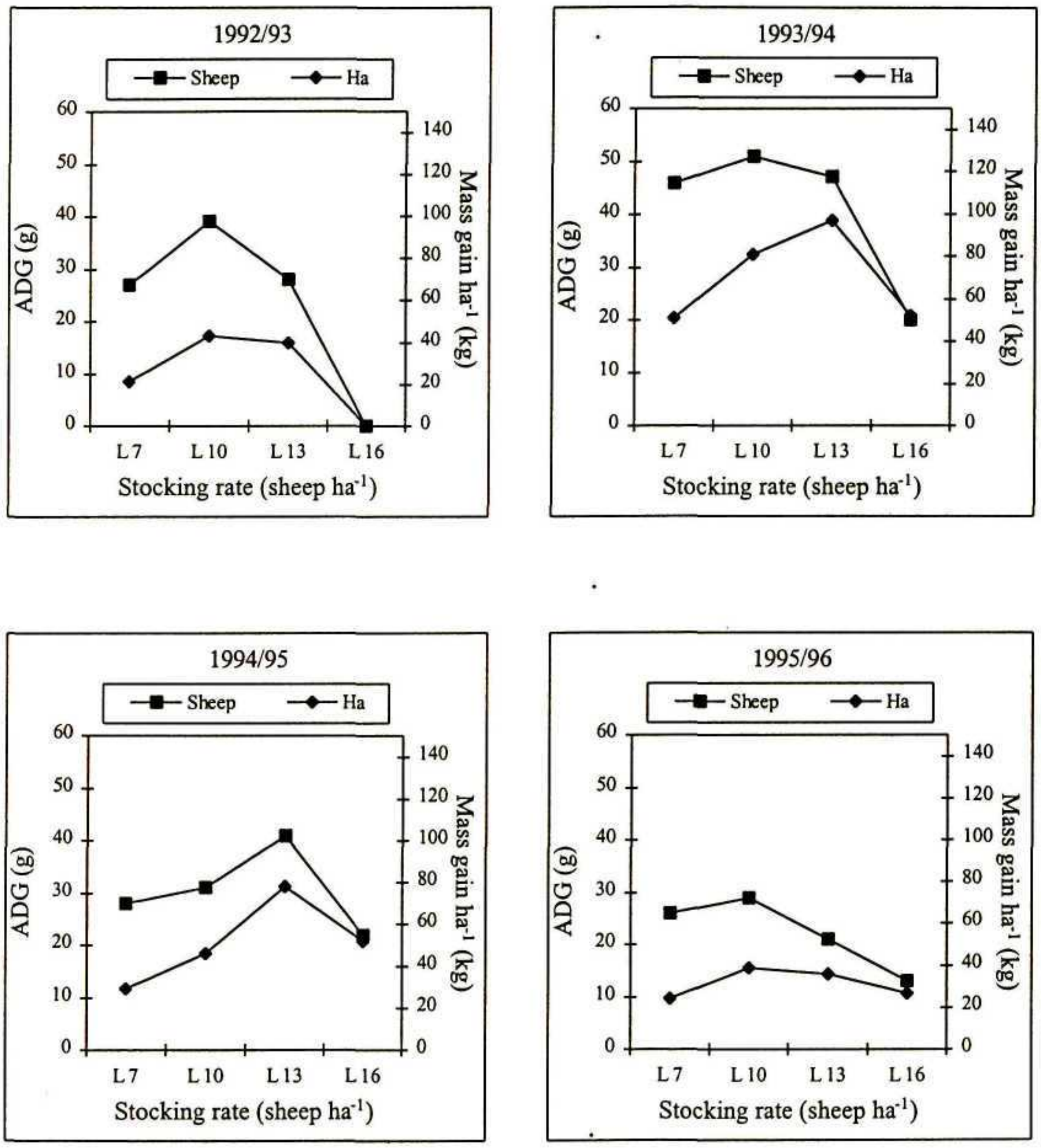
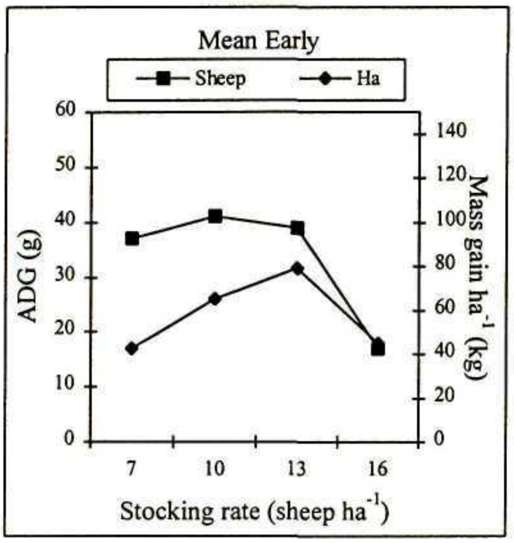
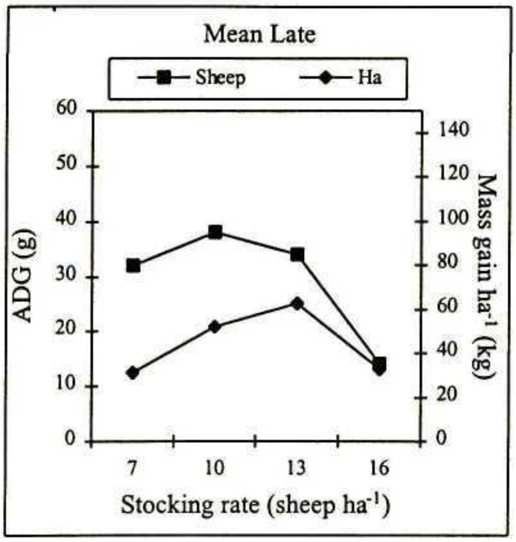


Figure 3.1 (b) Average daily gain (ADG) (g) and gain ha^{-1} (kg) for the late time of stocking treatments during the first four seasons





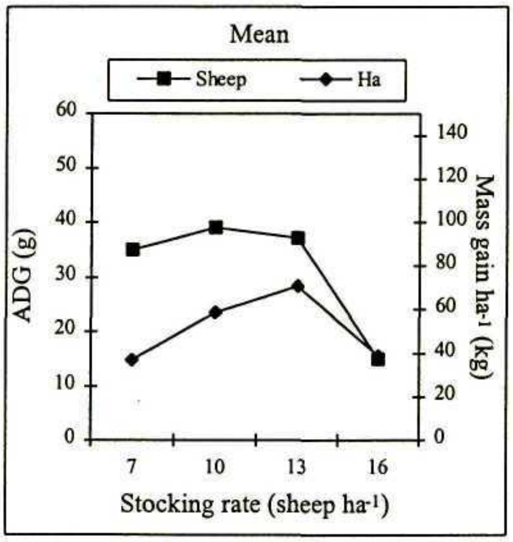


Figure 3.1 (c) Mean average daily gain (ADG) (g) and gain ha^{-1} (kg) for the early and late time of stocking treatments for the first four seasons, as well as the overall mean

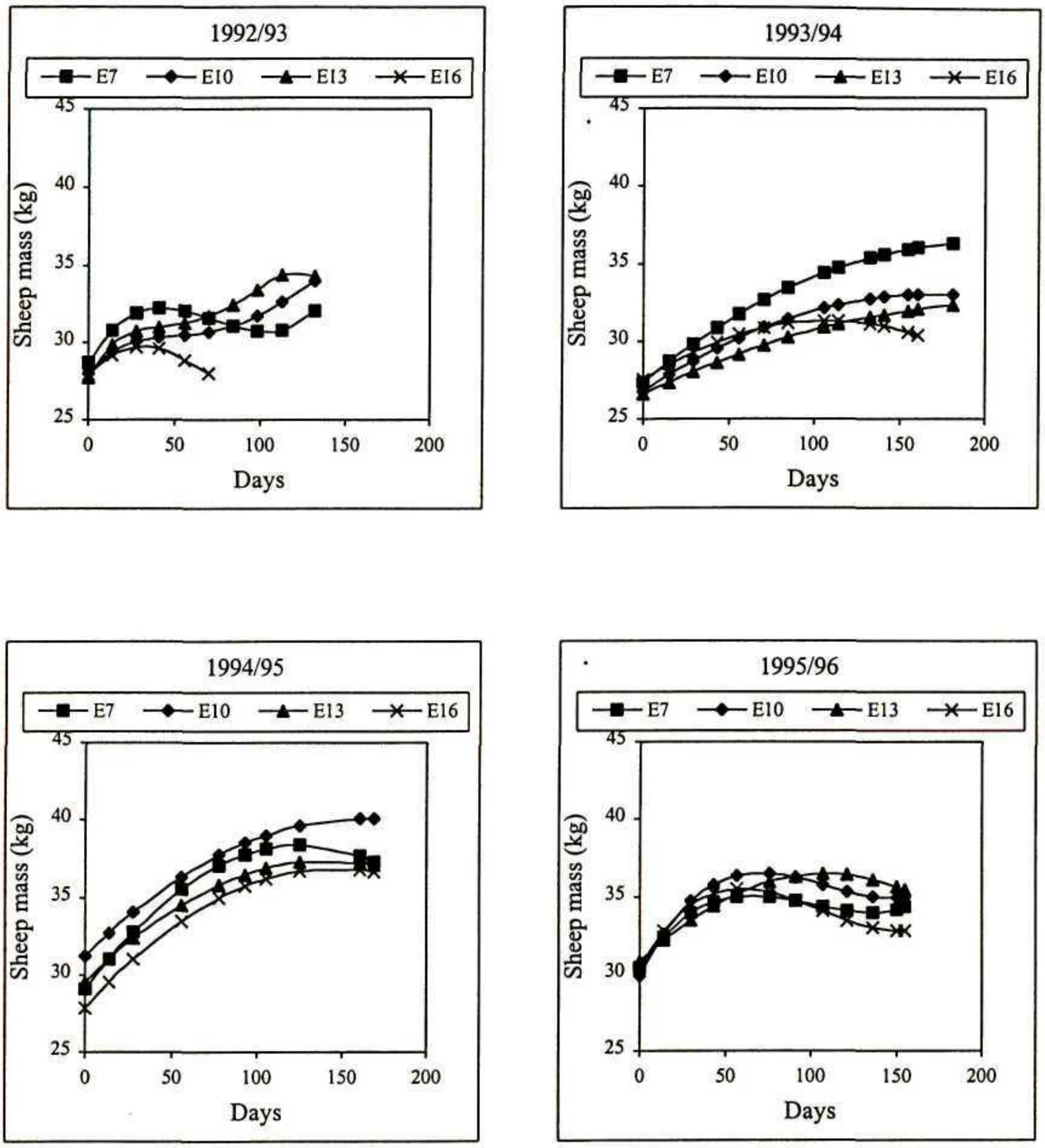


Figure 3.2 (a) Sheep mass changes (kg) during the first four seasons for the early time of stocking treatments

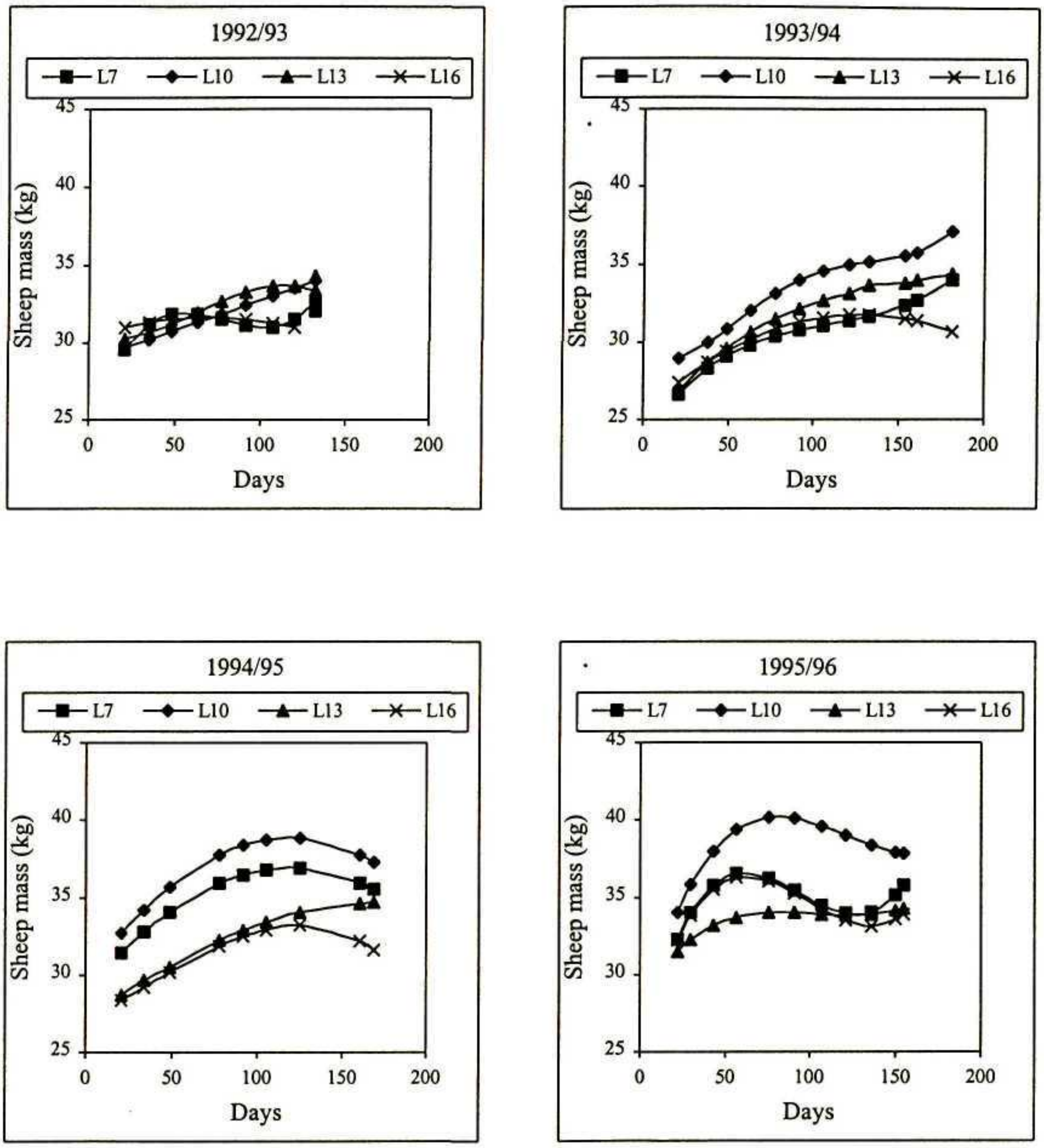


Figure 3.2 (b) Sheep mass changes (kg) during the first four seasons for the late time of stocking treatments

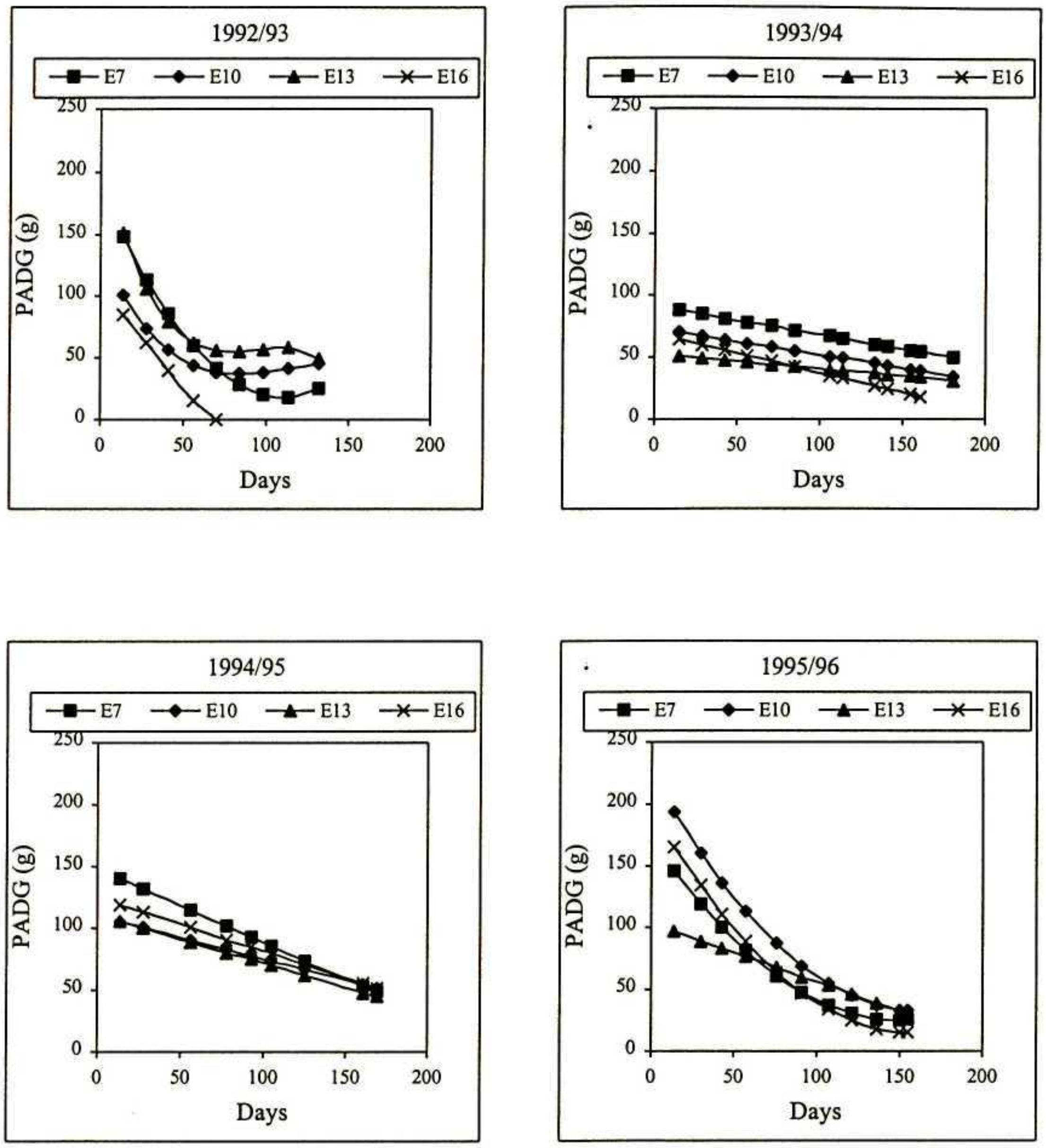


Figure 3.3 (a) Progressive average daily gain (PADG) (g) during the first four seasons for the early time of stocking treatments

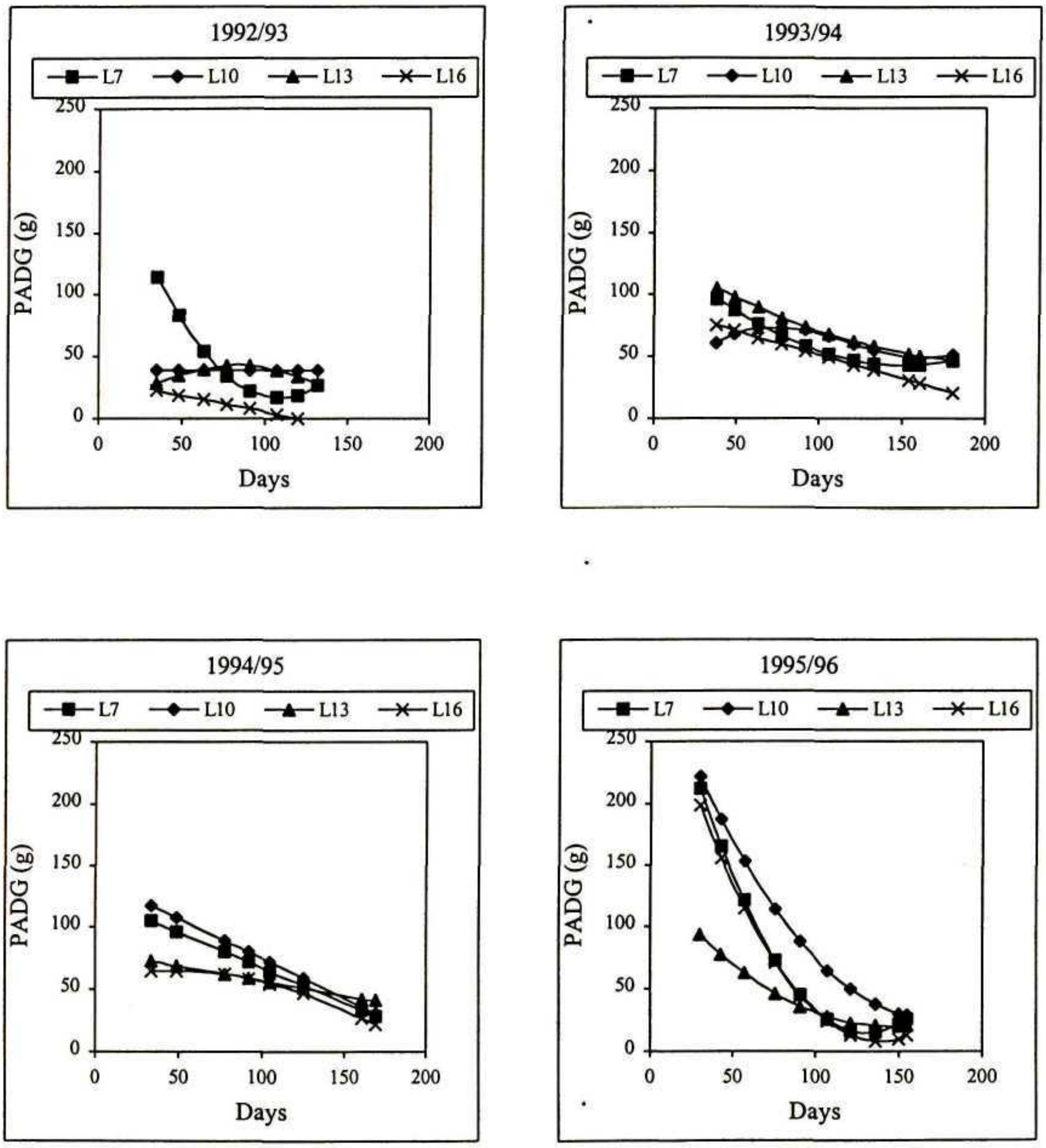


Figure 3.3 (b) Progressive average daily gain (PADG) (g) during the first four seasons for the late time of stocking treatments

CHAPTER 4

TRIAL 1

EFFECT OF STOCKING RATE AND TIME OF STOCKING ON FORAGE QUALITY

4.1 Determination of quality of material available

Sheep, fistulated at the oesophagus, were used to obtain samples from which quality of forage selected by sheep could be estimated. Concurrently, samples of standing herbage were also collected for quality analysis. The samples were collected at the time of stocking, at approximately two weekly intervals until December and at approximately monthly intervals from January until destocking at the end of the season. Quality was determined for the first three seasons of the trial period.

The fistulated sheep were kept in a veld camp close to the trial site. The camp was burnt every year to ensure that the diet of the fistulated sheep was comparable to those on the trial. Two fistulated sheep were placed on each treatment on the sampling day, and the samples were then pooled to obtain one sample per treatment.

Twenty herbage samples were located using 300 mm square quadrats placed systematically throughout each camp. The grass in each quadrat was cut at a height of 20 mm above ground or tuft-base level. The twenty samples per camp were pooled to obtain one sample per camp.

The material from the fistula samples was squeezed using four layers of cheesecloth. The liquid fraction was discarded. The solid fraction of the fistula samples and the herbage samples were oven dried at 50 °C. The contents of crude protein (CP) were determined using macro-Kjeldahl digestion (AOAC 1980) and *in vitro* digestible organic matter

(IVDOM) were determined using the method of Tilley & Terry (1963), as modified by Engels & van der Merwe (1967).

4.2 Results

Both the quality at time of stocking and the quality throughout each season are important in determining livestock performance. Apart from the expected quality decline with time during the season, the time of stocking and stocking rate treatments influenced the quality of the herbage available and the herbage selected by experimental animals. Polynomial curves were fitted to the CP and IVDOM data for each season, and are summarised in Tables 4.1 to 4.4.

4.2.1 Effect of time of stocking on quality at the beginning of the grazing season

The three-week period between the early and late time of stocking had a substantial effect on the veld quality at the times of stocking. The design of the trial allowed for using stocking rate as replication for the initial quality and quantity sampling at the beginning of a season, before treatments were applied. The differences in quality were thus analysed using analysis of variance.

The CP levels of the samples collected at the late time of stocking were generally lower than the levels of the samples collected at the early time of stocking (Table 4.5). The CP levels of the fistula samples were consistently higher than the clipped samples ($P<0.001$). This trend was consistent over all three years, and for both times of stocking.

The IVDOM levels of the samples collected at the late time of stocking were generally lower than the levels of the samples collected at the early time of stocking (Table 4.6). The IVDOM levels of the fistula samples were unexpectedly similar to the clipped samples ($P=0.329$).

4.2.2 Seasonal variations in quality

The veld quality at the beginning of the seasons has been discussed above. The variations in quality over the duration of the grazing seasons will be discussed in terms of time during the season, stocking rate, time of stocking and sampling method (fistula and clipped samples) for both CP and IVDOM.

Crude protein levels declined consistently over the duration of the grazing season in all treatments (Figure 4.1). The differences in crude protein levels noted at the beginning of the grazing season for the two times of stocking declined as the season progressed. There were no consistent differences during the latter part of the season and the crude protein levels of the early and late treatments were similar at the end of the season.

Crude protein levels tended to be higher in the heavier stocking rate treatments. The trends were not always consistent, and it appears that the interaction of quantity with CP may be more important in determining livestock performance than CP alone.

There were marked differences in the crude protein levels of the fistula and clipped samples. Consistent with the trend reported above for the early season quality, the crude protein of the fistula samples was substantially higher than the clipped samples. The ability of the sheep to select for high crude protein is obvious. The variability between stocking rates in the CP levels of the clipped samples was markedly less than in the fistula samples.

In a similar manner to the crude protein, the IVDOM levels declined consistently over the duration of the growing season for all treatments (Figure 4.2).

The significant differences observed between the early and late times of stocking at the beginning of the grazing season were not maintained over the duration of the grazing season. The differences soon became small and inconsistent. The IVDOM levels of the early and late treatments were generally similar at the end of the season. The effect of stocking rate on IVDOM was inconsistent.

There was a tendency for IVDOM of the fistula samples to be higher than the clipped samples over the duration of the season, but the magnitude and consistency of the trend was less than that observed for crude protein. This indicates that either the sheep do not select as efficiently for IVDOM, or that IVDOM is less affected by the treatments applied.

4.3 Relative importance of CP and IVDOM

Based on the above results, it appears that CP may play a more important role in sheep performance than IVDOM. The differences between the fistula and clipped samples were relatively greater for crude protein than for IVDOM. This may indicate that sheep select more efficiently for CP than for IVDOM. It also seems that CP may be a more efficient measure of quality than IVDOM.

The effects of the interaction between veld quality and quantity on livestock performance will be examined in more detail in Chapter 6.

Table 4.1 Polynomial models of variation in CP over time (Days) for the fistula samples during the 1992/93, 1993/94 and 1994/95 seasons for the early (E) and late (L) times of stocking at stocking rates of 16, 13, 10 & 7 sheep ha^{-1} (in all cases $P < 0.001$)

Season	**Variable**	**E16**	**E13**	**E10**	**E7**
1992/93	Constant	16.71	15.75	16.56	16.22
	Days	-0.1441	-0.165	-0.0779	-0.3360
	$Days^2$	0.000952	0.00383	0.000360	0.00612
	$Days^3$		-0.0000226		-0.0000297
	R_a^2	52.6	55.2	33.1	57.1
		L16	**L13**	**L10**	**L7**
	Constant	7.83	14.973	12.593	9.31
	Days	0.311	-0.0355	-0.02145	0.1059
	$Days^2$	-0.00446			-0.000732
	$Days^3$	0.0000169			
	R_a^2	72.9	63.7	38.2	18.6
1993/94		**E16**	**E13**	**E10**	**E7**
	Constant	18.21	13.443	17.51	16.26
	Days	-0.2644	-0.02597	-0.262	-0.0891
	$Days^2$	0.00364		0.00303	0.000274
	$Days^3$	0.0000152		-0.0000102	
	R_a^2	81.3	65.9	57.4	63.1
		L16	**L13**	**L10**	**L7**
	Constant	13.28	11.442	12.774	8.046
	Days	-0.02054	0.0129	-0.01047	0.0532
	$Days^2$		-0.0001397		-0.000284
	R_a^2	49.6	71.8	71.6	58.8
1994/95		**E16**	**E13**	**E10**	**E7**
	Constant	15.068	15.67	14.158	13.92
	Days	-0.1157	-0.028	-0.01832	-0.0564
	$Days^2$	0.001722			0.000194
	$Days^3$	-0.0000072			
	R_a^2	75.5	51.3	75.5	75.7
		L16	**L13**	**L10**	**L7**
	Constant	13.177	14.284	14.76	14.3
	Days	-0.00941	-0.02875	-0.02323	-0.0682
	$Days^2$				0.000348
	R_a^2	94.4	67.4	77.2	46.9

Table 4.2 Polynomial models of variation in IVDOM over time (Days) for the fistula samples during the 1992/93, 1993/94 and 1994/95 seasons for the early (E) and late (L) times of stocking at stocking rates of 16, 13, 10 & 7 sheep ha^{-1} (in all cases $P < 0.001$)

Season	Variable	E16	E13	E10	E7
1992/93	Constant	67.2	69.86	68.3	69.4
	Days	-0.674	-0.6172	-0.916	-0.506
	$Days^2$	0.00403	0.002956	0.01345	0.00263
	$Days^3$			-0.0000719	
	$Days^4$				
	R_a^2	66.4	97.4	87.8	63.2
		L16	**L13**	**L10**	**L7**
	Constant	68.87	56.86	60.93	60.8
	Days	-0.467	0.049	-0.1276	-0.221
	$Days^2$	0.0019	-0.00161		
	$Days^3$				
	R_a^2	69	83.1	31.1	38.8
1993/94		**E16**	**E13**	**E10**	**E7**
	Constant	63.32	59.64	67.38	62.88
	Days	-0.1896	-0.1008	-0.2429	-0.2027
	$Days^2$			0.000501	0.000579
	R_a^2	79.6	67.7	85	70.3
		L16	**L13**	**L10**	**L7**
	Constant	62.02	54.64	55.05	52.06
	Days	-0.1357	-0.048	0.0266	0.158
	$Days^2$			-0.000661	-0.00284
	$Days^3$				0.0000104
	R_a^2	82.1	56.9	80	53.2
1994/95		**E16**	**E13**	**E10**	**E7**
	Constant	54.35	50.76	61.08	60.23
	Days	0.4033	0.666	-0.0804	-0.0071
	$Days^2$	-0.00764	-0.01256		-0.000982
	$Days^3$	0.0000302	0.0000512		
	R_a^2	95.4	85.8	79	92.7
		L16	**L13**	**L10**	**L7**
	Constant	71.09	61.681	58.39	59.228
	Days	-0.517	-0.1704	0.084	-0.1546
	$Days^2$	0.002492	0.000402	-0.001524	0.0006241
	R_a^2	85.2	98.9	94.3	98.9

Table 4.3 Polynomial models of variation in CP over time (Days) for the clipped herbage samples during the 1992/93, 1993/94 and 1994/95 seasons for the early (E) and late (L) times of stocking at stocking rates of 16, 13, 10 & 7 sheep ha^{-1} (in all cases $P < 0.001$)

Season	**Variable**	**E16**	**E13**	**E10**	**E7**
1992/93	Constant	13.83	15.04	13.07	12.596
	Days	-0.309	-0.1515	-0.2034	-0.1497
	$Days^2$	0.00429	0.000661	0.00402	0.000807
	$Days^3$	-0.0000171		-0.0000207	
	R_a^2	61	72.9	50.1	95.1
		L16	**L13**	**L10**	**L7**
	Constant	11.783	12.02	11.106	12.551
	Days	-0.0846	-0.1093	-0.04210	-0.1134
	$Days^2$	0.0003742	0.000557		0.000608
	R_a^2	94.7	73	78.8	86.6
1993/94		**E16**	**E13**	**E10**	**E7**
	Constant	12.38	12.9	13.275	13.651
	Days	-0.0444	-0.1012	-0.1106	-0.1424
	$Days^2$		0.000337	0.000370	0.000504
	R_a^2	50.2	66.7	87.8	89.7
		L16	**L13**	**L10**	**L7**
	Constant	10.693	11.95	11.9	11.564
	Days	-0.0631	-0.1029	-0.104	-0.0808
	$Days^2$	0.000156	0.000358	0.000350	0.0002272
	R_a^2	88.5	80.8	78.5	96.2
1994/95		**E16**	**E13**	**E10**	**E7**
	Constant	13.557	13.582	12.786	13.053
	Days	-0.1039	-0.1155	-0.1079	-0.1183
	$Days^2$	0.000318	0.000396	0.000366	0.000413
	R_a^2	91.5	89.6	89.2	90.3
		L16	**L13**	**L10**	**L7**
	Constant	14.180	10.631	10.295	11.115
	Days	-0.2582	-0.0715	-0.05491	-0.08849
	$Days^2$	0.002418	0.0002065	0.0001131	0.0002808
	$Days^3$	-0.000007			
	R_a^2	90.2	91	98.7	98.8

Table 4.4 Polynomial models of variation in IVDOM over time (Days) for the clipped herbage samples during the 1992/93, 1993/94 and 1994/95 seasons for the early (E) and late (L) times of stocking at stocking rates of 16, 13, 10 & 7 sheep ha^{-1} (in all cases $P < 0.001$)

Season	**Variable**	**E16**	**E13**	**E10**	**E7**
1992/93	Constant	59.91	63.64	64.09	57.75
	Days	-0.609	-0.455	-0.1836	0.021
	$Days^2$	0.00313	0.00091		-0.00857
	$Days^3$				0.0000533
	R_a^2	48	83.4	82.5	93.3
		L16	**L13**	**L10**	**L7**
	Constant	68.31	73.52	62.46	61.91
	Days	-0.2335	-0.4043	-0.157	0.042
	$Days^2$				-0.001445
	R_a^2	86	80.8	95.5	92
1993/94		**E16**	**E13**	**E10**	**E7**
	Constant	67.22	63.19	61.2	69.65
	Days	-0.2284	-0.1753	-0.1505	-0.3818
	$Days^2$				0.001029
	R_a^2	92.4	94.3	94.5	96
		L16	**L13**	**L10**	**L7**
	Constant	63.14	68.96	66.79	66.11
	Days	-0.1873	-0.3988	-0.352	-0.3660
	$Days^2$		0.001145	0.000942	0.001081
	R_a^2	91.6	93.3	95.2	92.7
1994/95		**E16**	**E13**	**E10**	**E7**
	Constant	66.8	62.14	61.33	57.77
	Days	-0.3738	-0.3265	-0.3141	-0.2569
	$Days^2$	0.001078	0.000732	0.000906	0.000548
	R_a^2	98.2	96.9	95.8	95.5
		L16	**L13**	**L10**	**L7**
	Constant	64.44	69.31	61.15	63.32
	Days	-0.3720	-0.4325	-0.3117	-0.2943
	$Days^2$	0.001033	0.001183	0.000713	0.000643
	R_a^2	95	97.7	93	98

Table 4.5 Crude protein levels (%) of fistula and clipped herbage samples taken at the early and late times of stocking over the first three seasons. Significance of the differences in CP levels between early and late treatments and between fistula and clipped samples is shown

Season	Sample	Early	Late	Significance level (early vs. late)
1992/93	Fistula	16.31	12.53	
	Clipped	13.64	10.20	
1993/94	Fistula	16.36	11.49	
	Clipped	13.05	9.81	
1994/95	Fistula	14.71	13.49	
	Clipped	13.25	9.39	
Mean	Fistula	15.79	12.50	P<0.001
	Clipped	13.31	9.80	P<0.001
Significance level (fistula vs. clipped		P<0001	P<0.001	

Table 4.6 *In vitro* digestible organic matter levels (%) of herbage samples taken at the early and late times of stocking over the first three seasons. Significance of the differences in IVDOM levels between early and late treatments and between fistula and clipped samples is shown

Season	Sample	Early	Late	Significance level (early vs. late)
1992/93	Fistula	68.69	57.88	
	Clipped	61.34	62.40	
1993/94	Fistula	63.30	55.59	
	Clipped	65.32	59.80	
1994/95	Fistula	56.62	58.84	
	Clipped	62.01	57.54	
Mean	Fistula	62.87	57.44	P<0.001
	Clipped	62.89	59.91	P<0.05
Significance level (fistula vs. clipped)		P = 0.329	P = 0.329	

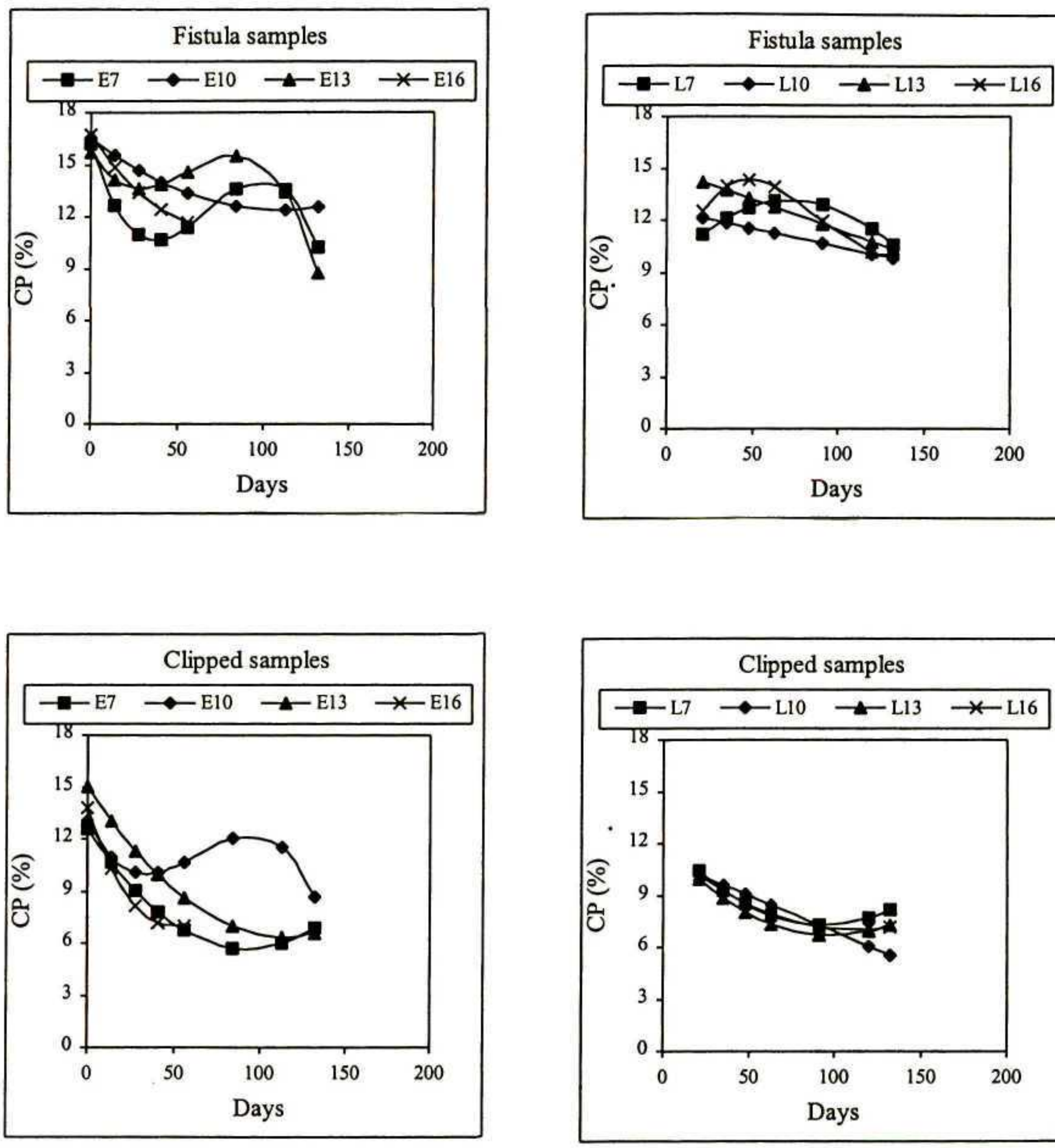


Figure 4.1 (a) Crude protein levels (%) during the 1992/93 season for both fistula and clipped samples for the early (E) and late (L) times of stocking and the 7, 10, 13 and 16 sheep ha^{-1} stocking rates

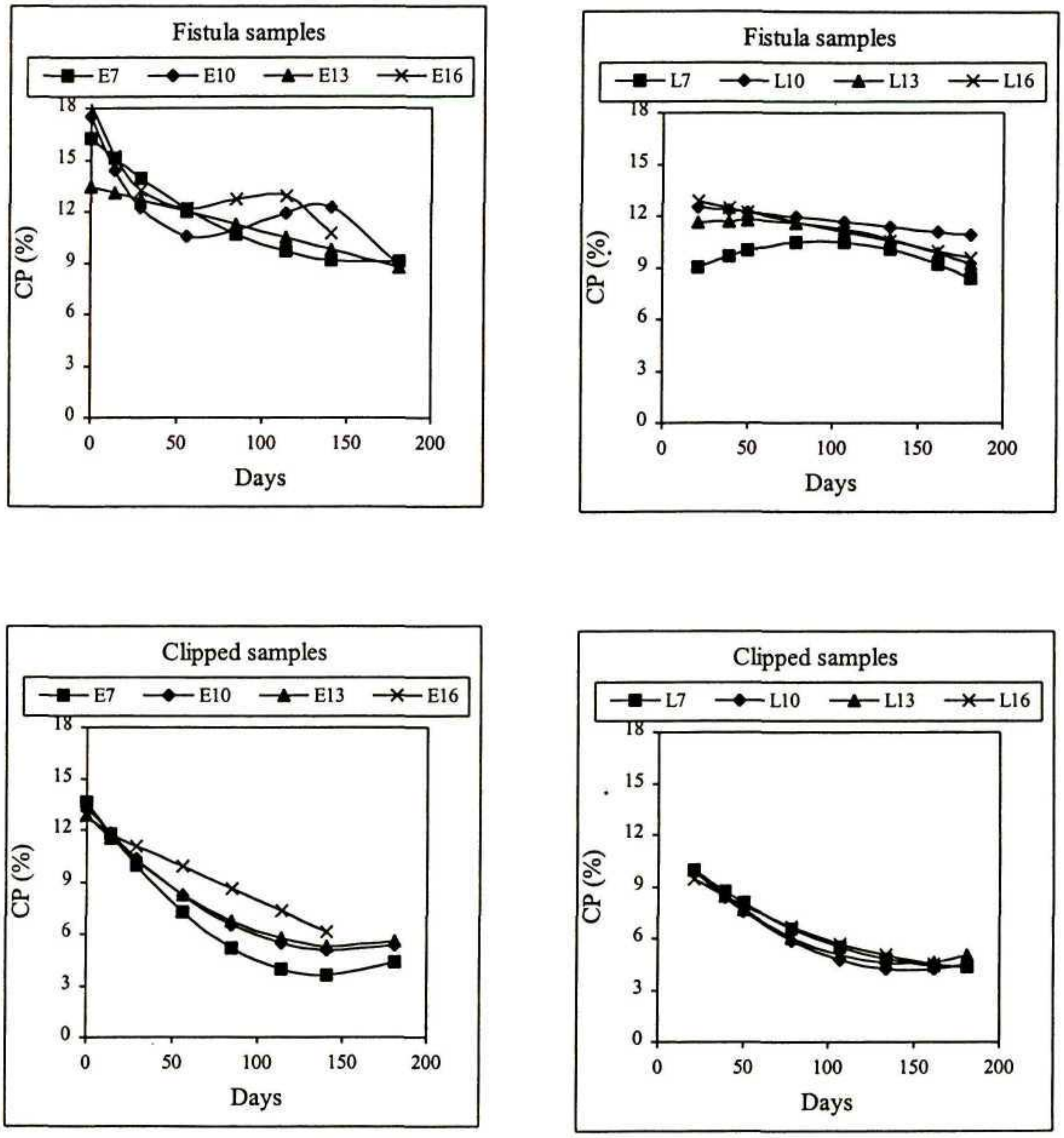


Figure 4.1 (b) Crude protein levels (%) during the 1993/94 season for both fistula and clipped samples for the early (E) and late (L) times of stocking and the 7, 10, 13 and 16 sheep ha^{-1} stocking rates

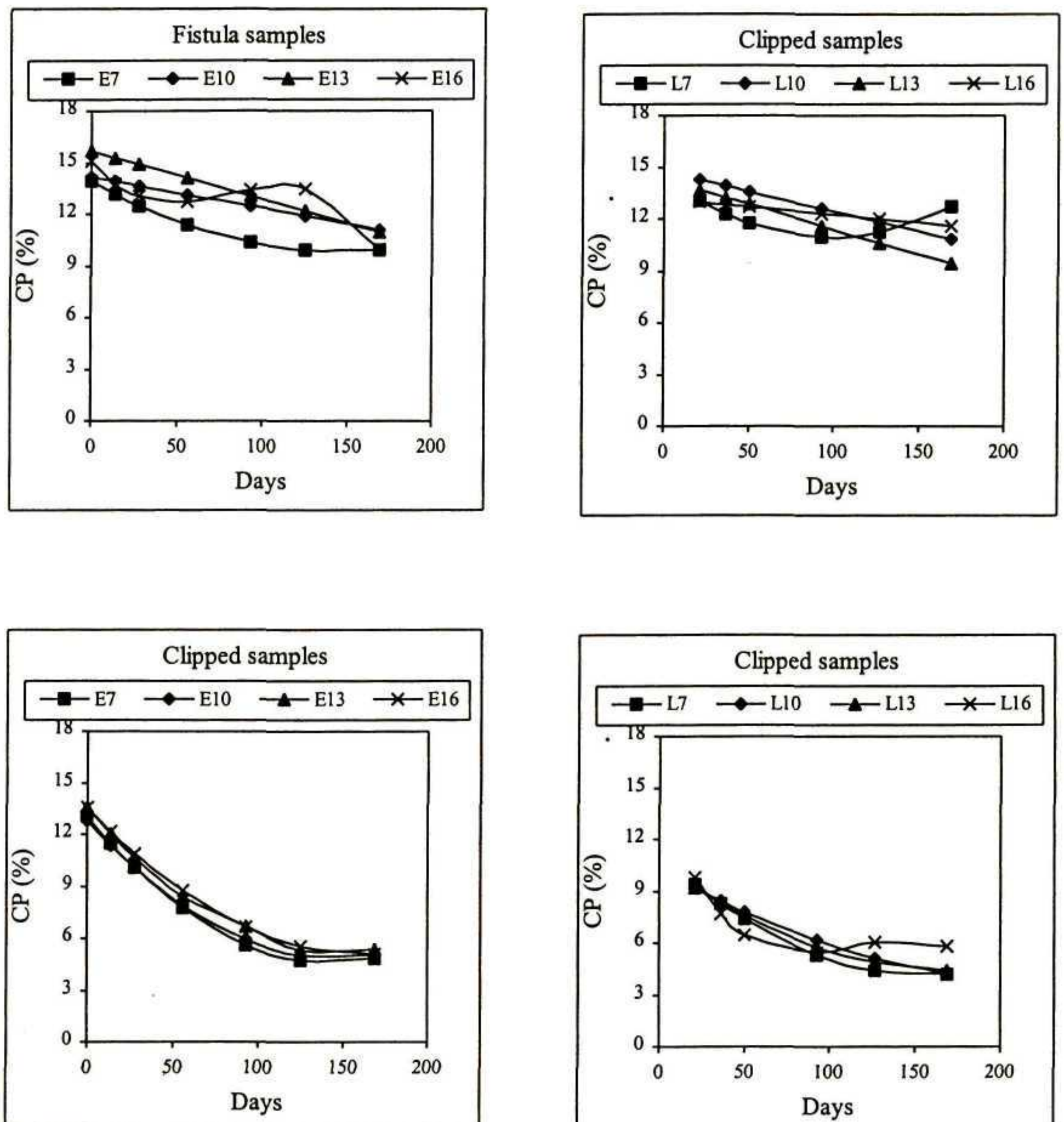


Figure 4.1 (c) Crude protein levels (%) during the 1994/95 season for both fistula and clipped samples

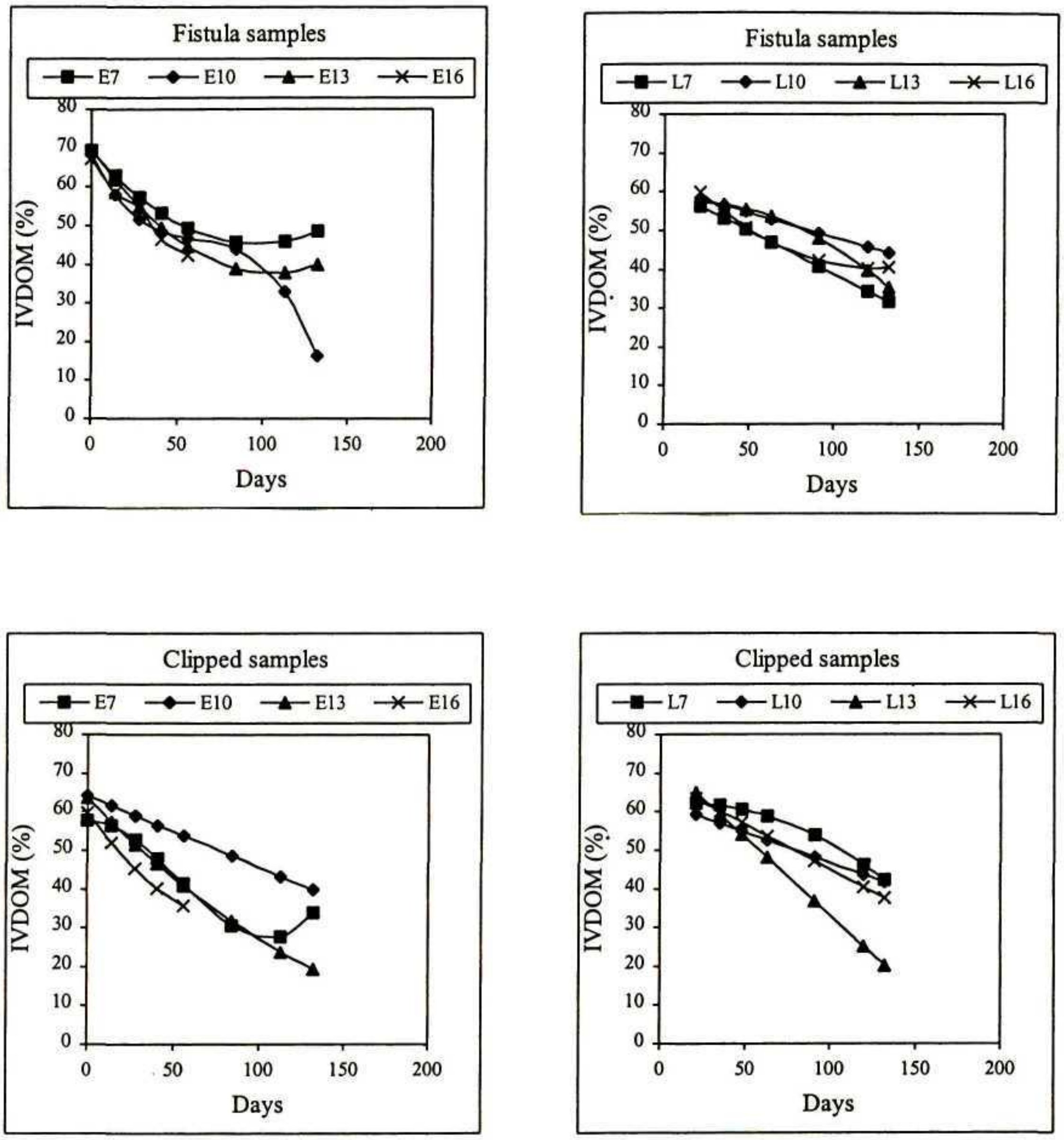


Figure 4.2 (a) *In vitro* digestible organic matter levels (%) during the 1992/93 season for both fistula and clipped samples

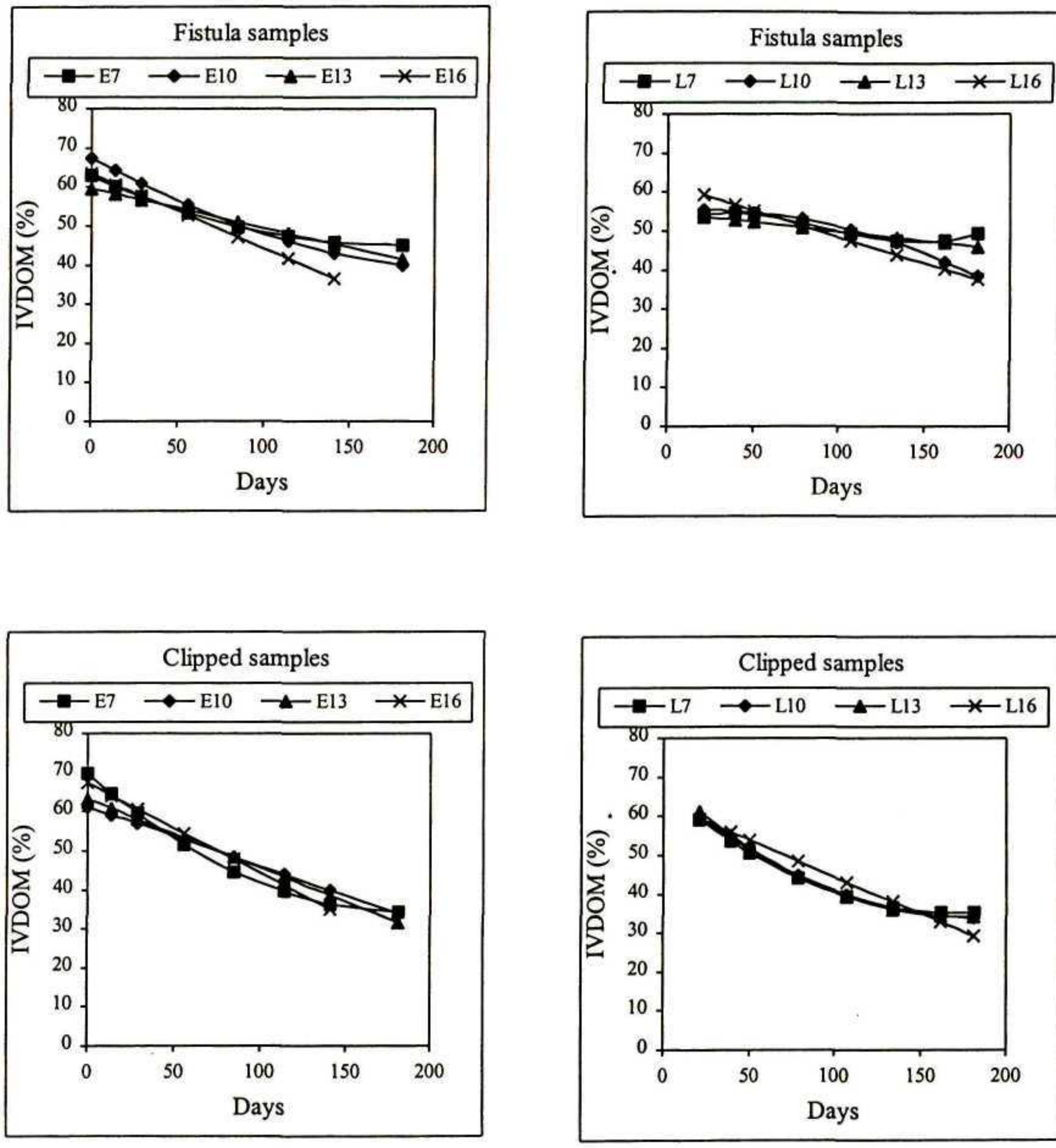


Figure 4.2 (b) *In vitro* digestible organic matter levels (%) during the 1993/94 season for both fistula and clipped samples

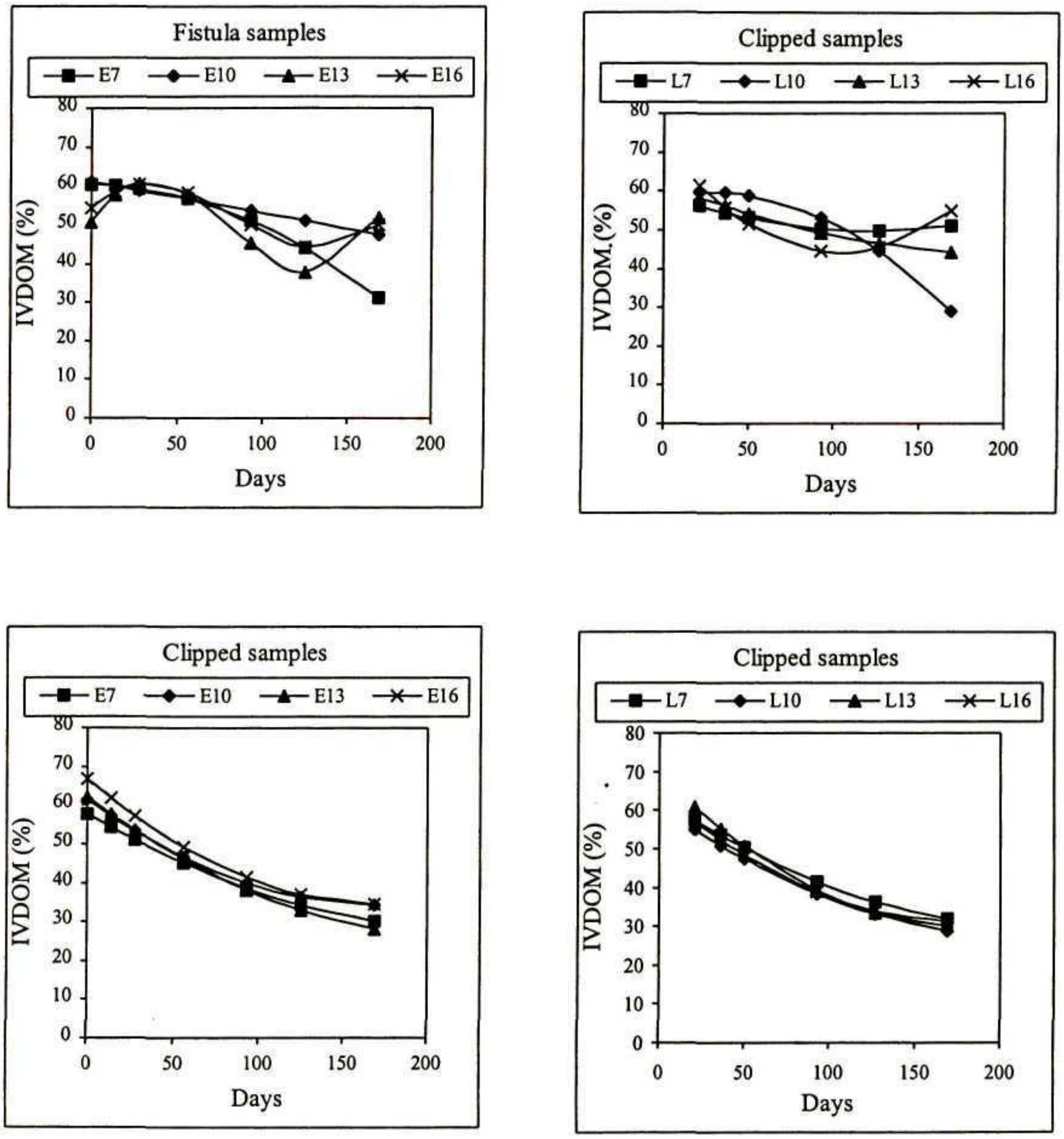


Figure 4.2 (c) *In vitro* digestible organic matter levels (%) during the 1994/95 season for both fistula and clipped samples

CHAPTER 5

TRIAL 1
THE EFFECT OF STOCKING RATE AND TIME OF STOCKING ON QUANTITY OF HERBAGE AVAILABLE DURING THE GROWING SEASON

5.1 Determination of quantity of material available

The quantity of herbage available on a species basis was estimated during the first three seasons using the dry-weight-rank techniques described in Appendix 1. Quantity was estimated at the time of stocking, at approximately two weekly intervals until December and at approximately monthly intervals from January until de-stocking at the end of the season.

Species were classified into palatability classes based on utilisation patterns in all treatments during the first three seasons (Table 5.1). The species that declined rapidly in terms of available dry matter during the season were classified as palatable. Those that accumulated in terms of available dry matter during the season were classified as unpalatable, while those that showed an inconsistent pattern or remained approximately constant were classified as intermediate. These trends were obtained from observing the data collected during the first three seasons, and are specific for the trial location and the Merino sheep used for the trial. Palatability is relative and depends on a number of factors including type of animal, age and production status of the animal, breed of animal, geographic location, stocking rate, the variety of species available, species composition and the amount of material available. This palatability classification should not be taken as absolute, but is considered adequate for the purposes of this trial.

Polynomial curves were fitted to the total standing herbage (kg DM ha^{-1}) (Y) over time (Days) (X) in each treatment as measured throughout the seasons (Table 5.2). A forward stepwise approach was adopted to avoid over-fitting. The highest order polynomials used were quartic curves.

5.2 Quantity of herbage available throughout the season for each treatment during the first three seasons.

The total standing herbage for each treatment is presented in Figure 5.1 for the first three seasons.

The extremely dry season during 1991/92 (prior to the initiation of the trial) and the dry early season of 1992/93 (up to December) resulted in low veld production during the 1992/93 season. The influence of the stocking rate treatments can be seen during the 1992/93 season. This season was the only season in which the herbage on some of the lighter stocking rate treatments increased towards the end of the season. Examination of the rainfall distribution reveals that mid- to late season rainfall during that season was relatively high compared to the long-term mean and the other two seasons under consideration. During the 1993/94 season, the influence of stocking rate can again be clearly seen. It is interesting that for the 1992/93 and 1993/94 seasons, the treatment induced differentiation in amounts of standing herbage are more pronounced for the early time of stocking treatment compared to the late time of stocking. During the 1994/95 season the response to stocking rate was not as pronounced as in the first two seasons.

Typically, the late time of stocking treatments consistently had more material available than the early time of stocking treatment throughout the season. In a similar manner, the lighter stocking rate treatments generally had more material available than the heavier stocking rates.

5.3 Total amount of herbage available at the beginning and end of each season

The total available herbage at the beginning (Table 5.3) and end (Table 5.4) of each season was determined as described in section 5.1. The design of the trial allowed for two different methods of statistical comparisons between the amounts of herbage available for each time of stocking at the beginning of the season. Firstly, an analysis of variance using the stocking rates as replications was carried out to determine the significance of differences in herbage mass between early and late times of stocking. These differences between the early and late times of stocking recorded in Table 5.3 were significant ($P<0.001$). Seasonal differences due to variations in climatic conditions resulted in differences between seasons. The differences between stocking rates were not significant.

The second method used was to fit straight lines to the stocking rate data for each time of stocking, and then test the fitted lines for differences in intercept and slope. This is based on a procedure outlined by Bransby *et al.*(1988) and is suitable for a trial design of this type. The procedure can, however, only be used if the data sets under consideration fit the criteria of linearity. Both methods of analysis were carried out on this data set, as it allowed for comparisons between the methods. In this case, reporting the formulae for the straight lines fitted to the initial herbage data for each time of stocking is not necessary, as the formulae are biologically meaningless. The procedure used involved fitting a straight line to the common data in a particular season, and then adding the time of stocking as a fitted term to the model. This allows for testing the significance of differences in intercept between the times of stocking. Differences in intercept in this case imply that the amounts of herbage present are significantly different. The next step involves fitting a stocking rate by time interaction term to test for homogeneity of slope of the lines. In this case, if the lines are parallel then the rate of change due to stocking rate treatment is statistically similar for each time of stocking. Again, in this case the stocking rate could not have had an impact on the amount of material present at the beginning of the season and the analysis was only carried out for comparative purposes.

The results of the two analyses were similar. Using the regression technique, for all three seasons the fitted lines were parallel for both times of stocking. The intercepts of the lines fitted to the early and late times of stocking were significantly different ($P<0.001$) for all three seasons.

This implies that the initial amount of herbage available for each stocking rate within a time of stocking treatment was statistically similar. The late time of stocking had significantly more herbage available at the beginning of each season. The dry conditions during 1991/92 and the early dry season of 1992/93 resulted in relatively small differences in amount of herbage available between the early and late treatments. The mean amount of herbage available for the early time of stocking was 277, 243 and 307 kg DM ha^{-1} respectively for the three seasons under consideration. The range from lowest to highest amounts is 64 kg DM ha^{-1}. The corresponding mean amounts for the late time of stocking treatments was 521, 865 and 730 kg.ha^{-1} respectively. The corresponding range for the late time of stocking is 344 kg DM ha^{-1}. It appears that it is relatively easy to estimate accurately the amount of herbage available and stock at the desired time. The differences in climatic conditions caused substantial differences in veld production during the twenty one day period between the early and late times of stocking.

The mean amount of material available for the early time of stocking was substantially more than the amounts available during a similar previous study (Barnes & Dempsey 1992). In that study, the amounts of herbage available at the time of early stocking were 80, 90 and 260 kg DM ha^{-1}. It must however, be noted that the previous study was carried out using a single stocking rate. In the present study, the amount of herbage present at the early time of stocking had to provide grazing for all stocking rates.

The amount of residual material at the end of each season varied tremendously between years, as a direct result of seasonal differences in climatic conditions and consequent herbage production. The length of the grazing season also played an obvious role. The date chosen for destocking the trial each year was selected by taking a number of factors into account. During the first season (1992/93), lack of grazing on most treatments prompted de-stocking. During the next two seasons, increased stock theft around the Easter period prompted de-stocking before the intended date of the end of April. Note that some treatments were de-stocked earlier than the rest, and this causes some distortion of the figures, particularly in the early time of stocking 16 sheep ha^{-1} treatment during the first two seasons. This variation in the length of the grazing periods between treatments within a season and between seasons precludes strict statistical analysis of the comparisons.

Examination of Table 5.4 reveals consistent and expected trends in terms of the effect of stocking rate and time of stocking on residual herbage. The differences in amount of residual herbage between the early and late times of stocking were somewhat smaller than at the beginning of the season. The mean amount of herbage at the beginning of the first three seasons on the early time of stocking treatments was 39 % of the amount of herbage on the late time of stocking treatments. The corresponding ratio at the end of the first three seasons was 87 %. It appears that the effect of early stocking on amount of herbage available becomes less pronounced throughout the duration of the season.

5.4 Mean amount of herbage available (kg DM ha^{-1} d^{-1}) for each treatment over the first three seasons

The mean herbage available per day was calculated from the polynomial models, using interpolation to derive daily availability of herbage, and is presented in Table 5.5. Note that the mean is not merely calculated from the start and end mass of herbage. These figures, although they may seem to be of academic value only, will be used in later analysis and give an indication of the effect of treatments on herbage availability. Examination of Table 5.5 reveals the impact of stocking rate and time of stocking on herbage availability. Increasing stocking rates over the range from 7 to 16 sheep ha^{-1} decreased the mean amounts of herbage available on average from 1004 to 650 (kg DM ha^{-1} day^{-1}). Expressed as amount of herbage $sheep^{-1}$ day^{-1}, the 7 sheep ha^{-1} treatment had 143 kg DM available per sheep, while the 16 sheep ha^{-1} treatment had 41 kg DM available per sheep (Table 5.6). Clearly the potential for selection in the heavy stocking rate treatments was severely restricted. Time of stocking also had a substantial impact on the mean amount of herbage available during each season, with the early time of stocking treatments consistently having less herbage available. Also of importance is the influence of season (climate) on herbage availability. The mean herbage available during the first season was 360 kg DM ha^{-1} day^{-1}, while during the third season this was 1128 kg DM ha^{-1} day^{-1}. The amount of herbage available per day on the heaviest stocking rate treatment during the second and third seasons was more than that available on the lightest stocking rate treatment during the first season. It appears that the effect of season (climate) can override the effects of applied treatments in terms of availability of herbage.

5.5 Total seasonal production (kg DM ha^{-1}) for each treatment over the first three seasons

The sheep intake was estimated based on sheep mass and mass gain (Meissner *et al.* 1983) using the sheep performance figures presented in chapter 3. The calculations were done in a manner similar to the method outlined by Hardy (1994). The intake figures are presented for each treatment in Table 5.7 as amount of herbage removed by sheep. Note that the figures represent the intake per treatment i.e. cumulative intake for all sheep per treatment. The trends in Table 5.7 reflect the cumulative mass of the sheep as well as the mass gains over the duration of the seasons.

Adding the mass of the residual herbage at the end of the season to the estimated intake of the sheep allows for estimating the veld production (kg DM ha^{-1}) during the season (Table 5.8), as well as the percentage utilisation (Table 5.9). The initial standing herbage was excluded from the calculation, as it was available for grazing and was considered to be part of the intake.

It is interesting to note that the stocking rate and time of stocking treatments do not appear to have a consistent impact on veld production within the season of treatment. During the 1992/93 season, veld production was lowest of the three seasons under consideration, with a mean production of 1701 kg DM ha^{-1}. The veld production during the following two seasons was 2689 and 2959 kg DM ha^{-1} respectively. The influence of climatic conditions on veld productivity was obvious during these three seasons. The fact that the grazing treatments did not have a consistent effect on the total veld production within the season of grazing is of interest. The interaction between stocking rate and climate is important and appears to be a key factor influencing livestock performance.

The estimation of herbage removal by sheep, coupled to the measurement of residual material at the end of each season, allowed for estimating the percentage utilisation for each treatment (Table 5.8). These figures again reflect expected trends based on the intensity of the grazing treatment. Of interest is the magnitude of the utilisation percentage. Grazing management advice commonly contains the statement "take half and leave half". The percentage utilisation of the 7 sheep ha^{-1} treatment (which is close to 1 LSU ha^{-1}) was consistently slightly under the 50 % level. The extremely high utilisation noted in some of the heavy stocking treatments was due to maintaining the grazing pressure until virtually no herbage remained. The sheep were monitored on a daily basis at this stage and removed at the point where intake was negatively affected by low herbage availability.

5.6 Effect of treatments on the quantity of various species available during the growing season.

A unique aspect of the present trial was that the measurements of available herbage at intervals throughout the growing season included estimations of individual species availability (kg DM ha^{-1}). The data are presented in Tables 5.10 to 5.33. The species in these tables have been grouped into palatable, intermediate and unpalatable groups according to the classification in Table 5.1. The total for each group is presented, along with the total for all species. Note that the data presented in these tables is actual data and not derived from polynomial curves fitted to the data. No attempt was made to fit curves to the individual species data.

Examination of the individual species data for all treatments reveals some interesting trends. The amounts of each species present at the beginning of each season varied substantially between treatments. This variation in species production is more pronounced than expected from examining proportional species composition differences between paddocks. Detailed visual examination of the trial site prior to the initiation of the trial also did not reveal such marked differences in species production between paddocks. This variation makes comparisons between the effect of treatments on species availability difficult. This variation in veld grass species production between paddocks highlights the difficulties of carrying out research on veld. However, some obvious trends do emerge.

5.6.1 Effects of grazing pressure on grass species during the 1992/93 season

During 1992/93 the early season veld production was low due to the previous dry season (51 % of mean annual rainfall) and the relatively low rainfall during September, October and November (59 % of mean annual rainfall for that period).

The rainfall was relatively greater during the remainder of the season with very good temporal distribution.

5.6.1.1 Palatable grasses

The availability of the palatable species declined consistently during the season on all the early stocking rate treatments (Tables 5.10 – 5.13). During the last sampling period, the palatable species available on the lighter stocking rates increased with a general increase in total species availability.

The late stocking rate treatments, having lighter grazing pressure, displayed different patterns (Tables 5.14 – 5.17). The available palatable material on the late 16 and 13 sheep ha^{-1} treatments declined until the sheep were removed. The palatable material showed an initial decline followed by an increase towards the rest of the season on the remainder of the late stocking rate treatments.

5.6.1.2 Intermediate grasses

The intermediate group of species was dominated largely by *Alloteropsis semialata*. This group of species clearly reflected the grazing pressure imposed by the treatments. In the lighter stocking rate treatments, the amount of material increased during the season. In the heavier stocking rate treatments, sheep were forced to graze the intermediate species, and the amount of material declined after an initial increase.

Similar patterns were observed in the late time of stocking treatments.

5.6.1.3 Unpalatable grasses

The amount of unpalatable material varied considerably between treatments. In those treatments where the total amount was too low to measure consistently over the season, the amounts available fluctuated. In those treatments with a substantial amount of unpalatable material, there was a consistent increase during the season.

5.6.2 Effects of grazing pressure on grass species during the 1993/94 season

The late season rainfall (March to June) during 1992/93 was relatively high (123 % of the long term mean). The rainfall during 1993/94 was below the long term mean (75 %). Veld production was approximately 1000 kg greater than the production during the previous season (Table 5.8). The impact of the relatively longer grazing season was reflected in the total herbage availability figures, in that total availability declined sharply near the end of the season (Tables 5.18 – 5.25). This was due to a decline in growth rate coupled to constant or increasing sheep intake.

5.6.2.1 Palatable grasses

The availability of palatable material again closely reflected the grazing pressure imposed by the treatments. The palatable material increased during the season in the lighter stocking rate treatments and declined in the heavier treatments. There was a general decline in amount of material towards the end of the season as observed in the total production figures.

5.6.2.2 Intermediate grasses

The amount of intermediate material available increased during the season and declined towards the end of the season over all treatments.

5.6.2.3 Unpalatable grasses

The amounts of unpalatable material available were again relatively low in all treatments.

5.6.3 Effects of grazing pressure on grass species during the 1994/95 season

The rainfall during the 1994/95 season was 73 % of the long term mean. Veld production was the highest recorded of the first three seasons (Table 5.8). The total herbage availability increased over the season in all treatments and declined towards the end of the season (Tables 5.26 – 5.33). The decline at the end of the season was similar to that noted in the previous season.

5.6.3.1 Palatable grasses

The available palatable material increased over all treatments for most of the season and declined towards the end of the season in a pattern similar to the total herbage available.

5.6.3.2 Intermediate grasses

The intermediate species availability increased until near the end of the season, when it declined slightly.

5.6.3.3 Unpalatable grasses

The unpalatable herbage increased during the season. Again, the amounts of unpalatable herbage were relatively low in most treatments.

5.7 Discussion

The determination of herbage availability on a species basis throughout each season for each treatment was a unique aspect investigated in this trial and provides new insight into the livestock / veld interaction. The stocking rate and time of stocking influenced the amount of herbage available, the species availability, the quality and the structure of the herbage available. These in turn influence livestock performance. The grazing patterns also impact the veld vigour and condition of the veld in terms of species composition.

It becomes obvious that the veld on the trial site was dynamic and varied tremendously between seasons. This was seen in the variations in herbage yield available at the early time of stocking (Table 5.3) for the stocking dates during each of the three seasons under consideration (Tale 3.3). Also, the tremendous differences in yield for the late time of stocking treatment during the three week period between early and late stocking reveals unpredictable seasonal variations in growth conditions. The impact of stocking rate, time of stocking and season on the amount of residual herbage at the end of each season was probably quantified for the first time for local veld. The percentage utilisation figures derived from the estimated intake and the residual herbage data also appear to be unique for local veld. These data allowed for the calculation of the mean amounts of herbage available per day on each treatment, and also per sheep. This holds potential for understanding the processes involved in livestock performance and effects of grazing on veld.

The herbage availability on a species basis during each season added a new dimension to the examination of the veld / livestock interaction. It allows for a higher level of understanding of the role of individual veld grass species both in terms of livestock performance as well as veld vigour and species composition. Previous studies have indicated that there are large differences between grass species in their predicted abilities to support livestock production (O'Reagain 1996a). Sward structure also plays an important role in determining livestock performance (O'Reagain 1996b). This was not measured in the present study.

The purpose of this chapter was to quantify the impact of the treatments on the herbage available. The impact on livestock performance will be covered in Chapter 6 and the impact on veld vigour and species composition in Chapter 7.

Table 5.1 Classification of veld grass species occurring on the trial site at Athole into palatability classes based on observed grazing patterns

Species	Palatability class
Andropogon appendiculatus	Palatable
Brachiaria brizantha	Palatable
Brachiaria serrata	Palatable
Ctenium concinnum	Palatable
Cynodon spp. *	Palatable
Digitaria flaccida	Palatable
Digitaria tricholaenoides	Palatable
Diheteropogon amplectens	Palatable
Eragrostis capensis	Palatable
Eulalia villosa	Palatable
Heteropogon contortus	Palatable
Hyparrhenia hirta	Palatable
Monocymbium ceresiiforme	Palatable
Setaria nigrirostris	Palatable
Setaria sphacelata	Palatable
Themeda triandra	Palatable
Tristachya leucothrix	Palatable
Alloteropsis semialata	Intermediate
Digitaria monodactyla	Intermediate
Eragrostis curvula	Intermediate
Eragrostis plana	Intermediate
Eragrostis racemosa	Intermediate
Eragrostis spp. *	Intermediate
Harpochloa falx	Intermediate
Melinis nerviglumis	Intermediate
Microchloa caffra	Intermediate
Panicum ecklonii	Intermediate
Panicum natalense	Intermediate
Stiburus conrathii	Intermediate
Trachypogon spicatus	Intermediate
Sedges	Intermediate
Aristida spp. *	Unpalatable
Cymbopogon excavatus	Unpalatable
Loudetia simplex	Unpalatable
Rendlia altera	Unpalatable

* More than one *Cynodon*, *Eragrostis* and *Aristida* species occurred that were very similar and were consequently grouped together. The *Eragrostis* species grouped together were additional to the individually identified *Eragrostis* species tabled above.

Table 5.2 Summary of polynomial models for total standing herbage (kg DM ha^{-1}) (Y) and time (Days) (X) for all treatment during the first three years of the trial period

Season	Treat	Regression formula	R_a^2	P<
1992/93	E16	$Y=368-15.50X+0.4432X^2-0.003812X^3$	99.2	0.05
	E13	$Y=268+3.37X-0.1151X^2+0.000706X^3$	88.4	0.001
	E10	$Y=222.4+4.87X-0.1506X^2+0.001044X^3$	81.6	0.001
	E7	$Y=285.3-6.06X+0.424X^2-0.00618X^3+0.0000271X^4$	87.0	0.001
	L16	$Y=543.8-9.5X+0.0447X^2$	93.4	0.01
	L13	$Y=591.9-10.06X+0.0569X^2$	90.2	0.01
	L10	$Y=565.3-4X+0.0699X^2$	90.0	0.001
	L7	$Y=482.9-5.65X+0.097X^2$	92.2	0.001
1993/94	E16	$Y=244.3+15.68X-0.25X^2+0.000923X^3$	97.1	0.001
	E13	$Y=319.6+12.26X-0.06638X^2$	94.6	0.001
	E10	$Y=256.4+13.94X-0.0616X^2$	91.4	0.001
	E7	$Y=259+20.4X-0.0746X^2$	94.4	0.001
	L16	$Y=832.4+20.71X-0.268X^2+0.000792X^3$	84.2	0.001
	L13	$Y=778+27.86X-0.341X^2+0.001003X^3$	88.2	0.001
	L10	$Y=929.3+3.98X+0.5863X^2-0.009064X^3+0.0000333X^4$	99.1	0.001
	L7	$Y=816.7+12.22X+0.286X^2-0.00533X^3+0.0000198X^4$	93.6	0.001
1994/95	E16	$Y=305.2+14.76X-0.06362X^2$	97.1	0.001
	E13	$Y=282.7+22.72X-0.1834X^2+0.000408X^3$	96.1	0.001
	E10	$Y=291.7+14.901X-0.06069X^2$	98.6	0.001
	E7	$Y=305.3+15.84X-0.06506X^2$	95.3	0.001
	L16	$Y=771.4+12.26X-0.0705X^2$	90.6	0.001
	L13	$Y=766.9+22.87X-0.2396X^2+0.000709X^3$	96.2	0.001
	L10	$Y=743.9+24.43X-0.2446X^2+0.000719X^3$	93.9	0.001
	L7	$Y=616.5+15.99X-0.0696X^2$	96.0	0.001

Table 5.3 Mean amount of herbage available (kg DM ha^{-1}) at the beginning of each season for each time of stocking and stocking rate during the first three years of the trial period

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	264	225	262	355	277
	Late	455	534	580	514	521
Mean		360	380	421	435	399
1993/94	Early	252	228	257	235	243
	Late	829	923	838	868	865
Mean		541	576	548	552	554
1994/95	Early	306	292	310	319	307
	Late	634	745	778	761	730
Mean		470	519	544	540	518
Mean	Early	274	248	276	303	275
	Late	639	734	732	714	705
Grand mean		457	491	504	509	490

Table 5.4 Mean amount of residual herbage (kg DM ha^{-1}) at the end of each season for each time of stocking and stocking rate for the first three years of the trial period

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	887	681	332	147	512
	Late	1064	1002	172	45	571
Mean		976	842	252	96	542
1993/94	Early	1516	750	391	141	700
	Late	1207	1251	590	512	890
Mean		1362	1001	491	327	795
1994/95	Early	1060	1006	803	875	936
	Late	1398	1343	1193	929	1216
Mean		1229	1175	998	902	1076
Mean	Early	1154	812	763	388	779
	Late	1223	1199	652	495	892
Grand mean		1189	1006	708	442	836

Table 5.5 Mean amounts of herbage available (kg DM ha^{-1}) for each season, time of stocking and stocking rate for the first three years of the trial period calculated from the polynomial curves fitted to the herbage availability data

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	444	273	230	226	293
	Late	575	637	271	223	427
Mean		510	455	251	225	360
1993/94	Early	1295	848	706	311	790
	Late	1379	1341	1128	1018	1217
Mean		1337	1095	917	665	1003
1994/95	Early	1029	977	952	951	977
	Late	1299	1356	1291	1170	1279
Mean		1164	1167	1122	1061	1128
Mean	Early	923	699	629	496	687
	Late	1084	1111	897	804	974
Grand mean		1004	905	763	650	830

Table 5.6 Mean amounts of herbage available (kg DM ha^{-1}) per sheep for each season, time of stocking and stocking rate for the first three years of the trial period calculated from the polynomial curves fitted to the herbage availability data

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	63	27	18	14	31
	Late	82	64	21	14	45
Mean		73	46	19	14	38
1993/94	Early	185	85	54	19	86
	Late	197	134	87	64	120
Mean		191	109	71	42	103
1994/95	Early	147	98	73	59	94
	Late	186	136	99	73	123
Mean		166	117	86	66	109
Mean	Early	132	70	48	31	70
	Late	155	111	69	50	96
Grand mean		143	91	59	41	83

Table 5.7 Mean amounts of herbage removed (kg DM ha^{-1}) by sheep for each season, time of stocking and stocking rate for the first three years of the trial period calculated from estimating sheep intake based on performance

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	804	941	1875	965	1146
	Late	819	1067	1434	1450	1193
Mean		812	1004	1655	1208	1169
1993/94	Early	1434	1890	2269	2311	1976
	Late	1147	1676	2057	2302	1796
Mean		1291	1783	2163	2307	1886
1994/95	Early	976	1643	2433	2835	1972
	Late	1081	1475	1921	2241	1680
Mean		1029	1559	2177	2538	1826
Mean	Early	1071	1491	2192	2037	1698
	Late	1016	1406	1804	1998	1556
Grand mean		1044	1449	1998	2017	1627

Table 5.8 Mean herbage production (kg DM ha^{-1}) for each season, time of stocking and stocking rate for the first three years of the trial period calculated from the herbage availability and sheep intake data

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	1691	1622	2207	1112	1658
	Late	1883	2069	1606	1495	1763
Mean		1787	1846	1907	1304	1711
1993/94	Early	2950	2640	2660	2452	2676
	Late	2354	2927	2647	2814	2686
Mean		2652	2784	2654	2633	2681
1994/95	Early	2036	2649	3236	3710	2908
	Late	2479	2818	3114	3170	2895
Mean		2258	2734	3175	3440	2902
Mean	Early	2226	2304	2701	2425	2414
	Late	2239	2605	2456	2493	2448
Grand mean		2232	2454	2578	2459	2431

Table 5.9 Mean percentage utilisation of herbage for each season, time of stocking and stocking rate

Season	Time of stocking	Stocking rate				Mean
		7	10	13	16	
1992/93	Early	48	59	85	87	70
	Late	44	52	89	97	71
Mean		46	56	87	92	70
1993/94	Early	49	71	86	94	75
	Late	48	57	77	81	66
Mean		49	64	82	88	70
1994/95	Early	46	60	74	74	64
	Late	43	53	62	68	57
Mean		45	57	68	71	60
Mean	Early	48	63	82	85	69
	Late	45	54	76	82	64
Grand mean		46	59	79	84	67

Table 5.10 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the early 7 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	13/10/92	27/10/92	11/11/92	24/11/92	10/12/92	5/1/93	3/2/93	22/2/93
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	41	13	6	7	5	11	6	8
Ctecon	34	50	61	44	43	8	4	7
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	16	8	8	4	3	6	7	14
Eracap	8	3	1	0	1	0	1	0
Eulvil	19	21	8	7	5	5	1	2
Hetcon	4	5	3	4	1	1	0	2
Hyphir	0	0	0	1	0	0	0	2
Moncer	6	1	4	2	2	1	2	2
Setnig	0	0	0	0	0	0	0	0
Setsph	0	0	0	0	0	0	0	0
Thetri	29	46	18	8	3	13	4	8
Trileu	9	10	14	30	20	13	12	15
Total Palatable	167	157	124	107	82	57	36	60
Allsem	14	9	9	14	9	10	4	5
Digmon	0	0	0	0	0	0	0	0
Eracur	3	1	3	7	14	1	1	6
Erapla	0	0	0	0	0	0	0	0
Erarac	1	2	7	2	5	3	6	2
Eraspp	0	0	0	0	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	0	0	0	0	0	0	0	0
Miccaf	1	0	3	0	3	0	0	1
Paneck	0	0	0	0	0	0	0	0
Pannat	0	8	5	2	3	3	1	5
Sticon	0	2	0	0	0	0	0	0
Traspi	3	13	6	23	35	68	79	108
SEDGES	0	2	4	4	6	11	8	18
Total Intermediate	22	37	37	52	73	95	100	144
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	0	3	0	0	0	0	0
Lousim	0	17	13	30	26	17	30	69
Renalt	69	98	157	196	221	359	284	614
Total Unpalatable	69	115	173	227	247	377	314	682
Other	6	1	1	1	0	1	2	0
Total	264	311	334	386	403	530	452	887

Table 5.11 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the early 10 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	13/10/92	27/10/92	11/11/92	24/11/92	10/12/92	5/1/93	3/2/93	22/2/93
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	37	19	8	2	5	13	8	18
Ctecon	13	27	22	4	1	2	1	3
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0	0
Digtri	2	0	0	0	0	0	0	0
Dihamp	8	5	6	4	4	13	6	97
Eracap	8	6	1	0	1	1	0	2
Eulvil	9	5	5	2	3	2	1	2
Hetcon	11	2	3	1	0	1	0	2
Hyphir	3	3	5	1	5	3	2	43
Moncer	7	3	3	2	4	4	2	6
Setnig	0	0	0	0	0	0	0	0
Setsph	0	0	0	0	0	0	0	0
Thetri	16	8	2	2	4	7	4	8
Trileu	17	13	19	5	8	10	10	302
Total Palatable	131	91	73	23	36	57	33	482
Allsem	52	94	106	142	122	127	150	94
Digmon	0	0	0	0	0	0	0	0
Eracur	5	8	4	1	0	2	0	1
Erapla	0	0	0	0	0	0	0	0
Erarac	5	4	7	2	3	3	3	5
Eraspp	0	0	0	0	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	0	1	0	0	0	0	0	0
Miccaf	1	1	0	0	0	1	0	0
Paneck	0	0	0	0	0	0	0	0
Pannat	0	8	5	3	2	1	1	1
Sticon	0	0	0	0	0	0	0	0
Traspi	0	12	10	2	1	1	1	0
SEDGES	1	2	1	2	2	13	14	6
Total Intermediate	65	128	133	152	130	147	169	107
Arispp	2	0	0	0	0	0	0	0
Cymexc	0	2	0	0	0	0	0	0
Lousim	0	12	2	3	2	1	2	1
Renalt	16	40	25	34	39	64	58	87
Total Unpalatable	18	54	27	37	41	65	61	88
Other	12	8	7	0	2	1	1	4
Total	226	282	241	211	209	270	264	681

Table 5.12 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the early 13 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	13/10/92	27/10/92	11/11/92	24/11/92	10/12/92	5/1/93	3/2/93	22/2/93
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	58	36	14	11	16	17	6	26
Ctecon	30	53	14	0	1	5	3	4
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0	0
Digtri	2	0	0	0	0	0	0	0
Dihamp	8	1	3	1	2	4	4	8
Eracap	3	1	0	0	0	0	0	1
Eulvil	3	1	1	2	0	0	0	1
Hetcon	7	2	4	0	0	0	0	1
Hyphir	0	0	0	0	0	0	0	0
Moncer	3	2	1	0	2	1	1	2
Setnig	0	0	0	0	0	0	0	0
Setsph	0	0	0	0	0	0	0	0
Thetri	4	1	2	2	1	3	2	1
Trileu	37	28	28	10	10	17	7	27
Total Palatable	155	125	67	28	33	47	23	73
Allsem	61	120	121	115	102	37	14	23
Digmon	0	0	0	0	0	0	0	0
Eracur	2	2	1	0	0	0	0	1
Erapla	0	0	0	0	0	0	0	0
Erarac	1	1	0	1	1	1	1	1
Eraspp	0	0	0	0	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	0	0	0	0	0	0	0	0
Miccaf	1	3	1	1	0	1	1	0
Paneck	0	0	0	0	0	0	0	0
Pannat	0	2	6	2	1	3	0	1
Sticon	0	0	0	0	0	0	0	0
Traspi	1	0	2	2	0	0	2	1
SEDGES	0	1	1	0	0	1	0	1
Total Intermediate	67	129	132	120	105	42	18	28
Arispp	0	0	0	0	0	0	0	0
Cymexc	1	0	0	0	0	0	0	0
Lousim	0	0	1	0	0	1	0	3
Renalt	33	53	76	96	94	187	152	229
Total Unpalatable	34	53	77	96	94	188	152	231
Other	8	3	2	0	1	0	1	0
Total	263	310	279	244	234	277	195	333

Table 5.13 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the early 16 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	13/10/92	27/10/92	11/11/92	24/11/92	10/12/92
Andapp	0	0	0	0	0
Brabri	0	0	0	0	0
Braser	63	7	7	5	9
Ctecon	34	21	3	4	3
Cynspp	0	0	0	0	0
Digfla	0	0	0	0	0
Digtri	4	1	0	0	0
Dihamp	21	2	8	4	5
Eracap	1	4	0	0	0
Eulvil	3	2	3	4	2
Hetcon	20	6	3	1	1
Hyphir	1	1	0	0	1
Moncer	4	3	2	1	5
Setnig	0	0	0	0	0
Setsph	0	0	0	0	0
Thetri	19	3	4	2	3
Trileu	28	12	9	5	7
Total Palatable	198	61	40	26	37
Allsem	40	65	21	11	13
Digmon	0	0	0	0	0
Eracur	3	4	1	0	0
Erapla	0	0	0	0	1
Erarac	1	2	1	0	1
Eraspp	0	0	0	0	0
Harfal	0	0	0	0	0
Melner	0	0	0	0	0
Miccaf	0	1	0	1	0
Paneck	0	0	0	0	0
Pannat	0	6	3	3	2
Sticon	0	0	0	0	0
Traspi	5	1	2	1	0
SEDGES	7	2	0	0	0
Total Intermediate	56	80	27	16	18
Arispp	0	0	0	0	0
Cymexc	1	0	0	0	0
Lousim	0	0	1	1	0
Renalt	82	82	127	183	156
Total Unpalatable	84	82	128	183	157
Other	18	1	1	1	0
Total	355	224	197	226	212

Table 5.14 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the late 7 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	2/11/92	19/11/92	30/11/92	14/12/92	21/1/93	22/2/92
Andapp	0	5	1	1	0	2
Brabri	4	0	2	0	0	0
Braser	89	58	44	20	30	69
Ctecon	5	10	2	2	0	4
Cynspp	4	0	2	0	0	0
Digfla	4	0	2	0	0	0
Digtri	0	0	0	0	0	5
Dihamp	34	22	12	4	5	24
Eracap	7	4	2	2	1	2
Eulvil	33	46	42	27	38	44
Hetcon	12	8	9	6	1	26
Hyphir	2	2	5	1	1	9
Moncer	13	5	3	2	4	9
Setnig	4	0	2	.0	0	0
Setsph	4	0	2	0	0	0
Thetri	106	115	152	122	235	319
Trileu	4	15	15	13	17	32
Total Palatable	326	291	296	199	331	545
Allsem	69	73	99	61	145	255
Digmon	4	0	2	0	0	0
Eracur	6	10	2	1	3	3
Erapla	1	3	5	0	0	0
Erarac	9	11	12	9	8	43
Eraspp	4	0	2	0	0	0
Harfal	0	0	0	0	0	0
Melner	4	0	2	0	0	0
Miccaf	0	1	0	0	1	2
Paneck	4	0	2	.0	0	0
Pannat	7	20	22	19	35	70
Sticon	1	0	0	0	0	0
Traspi	5	10	5	17	37	91
SEDGES	1	1	1	5	1	0
Total Intermediate	114	130	154	113	229	464
Arispp	0	0	2	0	0	5
Cymexc	0	0	0	0	0	0
Lousim	8	13	15	9	34	40
Renalt	5	4	4	0	14	8
Total Unpalatable	13	17	21	10	48	53
Other	3	10	0	0	1	3
Total	455	447	472	322	610	1065

Table 5.15 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the late 10 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	2/11/92	19/11/92	30/11/92	14/12/92	21/1/93	22/2/92
Andapp	3	4	7	2	3	2
Brabri	27	26	23	14	21	8
Braser	81	41	56	32	28	29
Ctecon	14	19	28	38	12	63
Cynspp	27	26	23	14	21	8
Digfla	27	26	23	14	21	8
Digtri	0	0	0	0	0	0
Dihamp	28	11	9	1	3	11
Eracap	2	1	1	1	1	0
Eulvil	10	4	8	1	10	2
Hetcon	2	1	2	3	2	5
Hyphir	3	9	6	0	2	3
Moncer	2	1	1	1	0	2
Setnig	27	26	23	14	21	8
Setsph	27	26	23	14	21	8
Thetri	15	26	24	44	31	68
Trileu	24	37	69	42	83	261
Total Palatable	321	284	325	235	281	487
Allsem	49	79	71	70	116	199
Digmon	27	26	23	14	21	8
Eracur	2	5	1	5	3	8
Erapla	1	0	1	2	3	5
Erarac	2	1	4	2	8	3
Eraspp	27	26	23	14	21	8
Harfal	0	0	0	0	0	0
Melner	27	26	23	14	21	8
Miccaf	2	1	0	0	9	0
Paneck	27	26	23	14	21	8
Pannat	6	4	16	13	12	32
Sticon	0	2	0	0	0	0
Traspi	9	11	26	27	53	117
SEDGES	1	3	3	1	6	7
Total Intermediate	180	212	215	174	295	404
Arispp	0	0	0	0	0	0
Cymexc	0	0	1	0	0	0
Lousim	1	8	12	4	15	37
Renalt	30	23	24	48	41	73
Total Unpalatable	31	31	36	52	56	111
Other	3	7	11	0	2	0
Total	534	535	587	460	634	1002

Table 5.16 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the late 13 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	2/11/92	19/11/92	30/11/92	14/12/92	21/1/93	22/2/92
Andapp	2	0	1	0	0	0
Brabri	0	0	0	0	0	0
Braser	133	89	53	14	9	17
Ctecon	37	4	1	2	0	0
Cynspp	0	0	0	0	0	0
Digfla	0	0	0	0	0	0
Digtri	0	0	0	0	0	0
Dihamp	58	22	10	1	3	4
Eracap	5	0	1	0	0	2
Eulvil	28	25	10	2	1	2
Hetcon	11	4	1	0	0	1
Hyphir	26	6	4	1	2	3
Moncer	16	3	2	1	1	1
Setnig	0	0	0	0	0	0
Setsph	0	0	0	0	0	0
Thetri	105	92	82	22	11	8
Trileu	11	24	9	4	0	4
Total Palatable	431	271	174	47	30	42
Allsem	62	70	86	23	13	10
Digmon	0	0	0	0	0	0
Eracur	22	11	27	14	5	2
Erapla	3	1	1	3	3	17
Erarac	6	9	9	5	4	5
Eraspp	0	0	0	0	0	0
Harfal	0	0	0	0	0	0
Melner	0	0	0	0	0	0
Miccaf	2	1	2	5	5	9
Paneck	0	0	0	0	0	0
Pannat	16	27	21	15	46	15
Sticon	0	0	0	0	0	0
Traspi	8	17	24	12	8	0
SEDGES	0	1	1	0	0	9
Total Intermediate	119	138	171	76	84	67
Arispp	0	1	0	0	0	0
Cymexc	0	0	0	0	0	0
Lousim	10	28	39	44	29	14
Renalt	20	11	8	27	49	49
Total Unpalatable	30	39	48	72	77	63
Other	0	16	3	2	1	0
Total	580	464	396	196	192	172

Table 5.17 Amounts of all grass species available (kg DM ha^{-1}) during the 1992/93 grazing season for the late 16 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	2/11/92	19/11/92	30/11/92	14/12/92	21/1/93	22/2/92
Andapp	0	0	0	0	0	0
Brabri	8	0	0	0	0	1
Braser	68	35	15	13	6	8
Ctecon	11	3	0	0	0	0
Cynspp	8	0	0	0	0	0
Digfla	8	0	0	0	0	0
Digtri	0	0	0	0	0	0
Dihamp	22	5	3	3	1	1
Eracap	2	2	0	0	0	0
Eulvil	50	49	24	10	2	1
Hetcon	14	5	3	0	0	0
Hyphir	3	1	0	1	0	1
Moncer	5	3	1	2	1	0
Setnig	8	0	0	0	0	1
Setsph	8	0	0	0	0	0
Thetri	63	45	28	6	2	1
Trileu	16	32	18	3	2	2
Total Palatable	293	178	94	43	15	17
Allsem	137	177	214	99	32	11
Digmon	8	0	0	0	0	0
Eracur	11	5	5	0	0	0
Erapla	4	1	0	1	0	2
Erarac	8	11	6	5	1	1
Eraspp	8	0	0	0	0	1
Harfal	0	0	0	0	0	0
Melner	8	0	0	0	0	0
Miccaf	2	2	3	0	0	0
Paneck	8	0	0	0	0	1
Pannat	8	11	1	2	0	1
Sticon	1	0	0	0	0	0
Traspi	1	14	15	2	0	0
SEDGES	1	5	4	5	1	1
Total Intermediate	204	227	250	117	35	18
Arispp	0	0	1	1	0	0
Cymexc	0	0	1	0	0	0
Lousim	3	18	6	0	0	0
Renalt	13	0	12	7	38	6
Total Unpalatable	15	18	19	8	39	7
Other	2	11	1	0	0	0
Total	515	434	363	168	89	68

Table 5.18 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the early 7 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	20/10/93	2/11/93	17/11/93	13/12/93	10/1/94	9/2/94	8/3/94	18/4/94
Andapp	1	1	0	2	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	38	82	109	63	27	19	11	8
Ctecon	7	11	0	0	0	0	0	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	8	6	4	4	16	9	5	1
Eracap	2	2	6	7	3	5	4	2
Eulvil	30	66	103	157	151	257	279	296
Hetcon	3	18	5	8	13	17	5	7
Hyphir	2	3	4	5	52	3	4	17
Moncer	4	5	1	2	0	1	4	0
Setnig	30	82	140	170	241	247	243	99
Setsph	0	0	0	0	0	0	0	1
Thetri	40	100	171	268	310	464	405	469
Trileu	13	24	37	26	39	48	28	32
Total Palatable	177	399	582	713	851	1072	988	931
Allsem	55	129	152	280	329	518	358	320
Digmon	0	0	6	6	8	15	17	31
Eracur	5	6	0	0	0	0	0	0
Erapla	0	0	0	0	0	0	0	0
Erarac	1	2	6	10	27	33	24	25
Eraspp	0	1	3	1	0	3	1	1
Harfal	0	0	0	0	0	0	0	0
Melner	3	3	0	0	0	1	1	0
Miccaf	1	4	0	0	2	0	1	0
Paneck	0	0	1	0	0	0	0	0
Pannat	0	0	6	8	41	79	20	37
Sticon	0	0	0	0	0	0	0	0
Traspi	0	6	14	14	67	79	111	121
SEDGES	1	3	1	5	3	3	2	1
Total Intermediate	68	153	189	325	477	731	534	535
Arispp	0	0	0	0	1	0	0	1
Cymexc	0	0	8	8	11	33	15	49
Lousim	3	4	0	7	6	4	1	0
Renalt	4	0	5	0	1	0	0	0
Total Unpalatable	8	4	14	15	19	37	17	50
Other	0	0	0	0	1	0	0	0
Total	252	556	785	1053	1347	1840	1539	1516

Table 5.19 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the early 10 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	20/10/93	2/11/93	17/11/93	13/12/93	10/1/94	9/2/94	8/3/94	18/4/94
Andapp	2	0	1	1	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	42	14	13	11	8	5	7	7
Ctecon	12	18	0	0	0	0	0	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	9	6	5	1	2	0	3	8
Eracap	1	1	4	6	8	19	11	6
Eulvil	10	22	77	94	72	22	40	24
Hetcon	8	22	22	22	7	8	3	5
Hyphir	20	15	21	19	12	11	15	18
Moncer	4	3	0	1	0	2	1	1
Setnig	3	3	5	11	11	13	24	4
Setsph	2	0	0	0	0	0	0	0
Thetri	35	107	217	225	175	205	235	184
Trileu	5	16	38	39	47	39	38	25
Total Palatable	152	228	403	432	342	324	377	282
Allsem	50	121	234	262	349	446	367	231
Digmon	0	0	1	2	1	3	2	6
Eracur	12	15	3	0	0	0	0	0
Erapla	0	0	0	0	0	0	0	0
Erarac	1	3	19	55	80	117	80	90
Eraspp	0	0	2	1	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	2	5	0	0	0	1	0	0
Miccaf	0	3	0	1	1	0	1	2
Paneck	0	1	1	0	0	0	0	0
Pannat	0	0	14	14	1	8	0	1
Sticon	0	0	0	0	0	0	0	0
Traspi	1	12	9	28	31	71	92	96
SEDGES	0	1	0	4	4	3	1	4
Total Intermediate	67	161	283	366	466	648	542	429
Arispp	0	0	0	3	2	26	13	0
Cymexc	0	0	17	12	39	79	73	6
Lousim	7	7	4	2	5	26	13	4
Renalt	2	3	6	0	0	0	0	0
Total Unpalatable	9	10	27	16	46	131	99	11
Other	0	1	4	.6	0	6	14	0
Total	228	399	717	820	855	1110	1033	750

Table 5.20 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the early 13 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	20/10/93	2/11/93	17/11/93	13/12/93	10/1/94	9/2/94	8/3/94	18/4/94
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	56	28	21	15	8	28	11	8
Ctecon	2	0	0	0	0	0	0	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	7	5	1	1	0	3	1	1
Eracap	1	2	7	7	2	16	4	1
Eulvil	16	28	38	10	10	7	3	3
Hetcon	2	14	1	3	4	0	3	0
Hyphir	1	0	1	.3	7	2	2	0
Moncer	2	3	1	0	0	1	3	0
Setnig	26	55	71	25	20	21	10	5
Setsph	0	0	0	0	0	0	0	0
Thetri	56	175	224	291	321	269	235	91
Trileu	6	14	20	17	24	27	36	23
Total Palatable	175	323	385	372	397	374	309	132
Allsem	68	162	227	317	406	430	304	232
Digmon	0	0	1	0	0	0	4	1
Eracur	1	7	0	0	0	0	0	0
Erapla	0	0	0	0	0	0	0	0
Erarac	1	6	10	14	21	23	19	2
Eraspp	0	0	1	2	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	2	4	0	.0	0	1	0	0
Miccaf	0	0	0	0	2	0	4	3
Paneck	0	1	1	0	0	0	0	0
Pannat	2	0	3	1	1	0	0	0
Sticon	0	0	0	0	0	0	0	0
Traspi	1	17	10	22	31	45	46	12
SEDGES	0	1	0	5	1	2	0	0
Total Intermediate	74	199	253	360	464	500	377	250
Arispp	0	0	1	0	0	0	0	2
Cymexc	0	0	5	7	10	13	2	1
Lousim	6	2	4	6	8	1	14	8
Renalt	2	6	3	0	0	0	0	0
Total Unpalatable	8	7	13	13	18	14	16	10
Other	0	0	0	·0	1	0	0	0
Total	257	529	651	745	879	889	702	392

Table 5.21 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the early 16 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	20/10/93	2/11/93	17/11/93	13/12/93	10/1/94	9/2/94
Andapp	0	1	0	0	0	0
Brabri	0	0	0	0	0	0
Braser	55	17	14	7	12	8
Ctecon	3	7	2	0	0	0
Cynspp	0	0	0	0	0	0
Digfla	0	0	0	0	0	0
Digtri	0	0	1	0	0	0
Dihamp	6	3	1	1	1	2
Eracap	0	1	1	3	2	2
Eulvil	11	27	13	5	4	3
Hetcon	7	2	2	2	1	2
Hyphir	7	13	12	5	12	4
Moncer	2	1	1	0	1	0
Setnig	2	7	11	7	1	1
Setsph	0	0	0	0	0	0
Thetri	38	113	144	23	19	12
Trileu	9	17	21	21	12	8
Total Palatable	141	210	223	75	65	42
Allsem	75	181	243	359	307	88
Digmon	0	0	1	2	1	2
Eracur	11	8	0	0	0	0
Erapla	0	0	0	0	0	0
Erarac	0	0	7	10	8	8
Eraspp	1	1	1	1	0	0
Harfal	0	0	0	0	0	0
Melner	1	2	0	0	0	2
Miccaf	1	0	0	0	1	0
Paneck	0	1	0	0	0	0
Pannat	0	0	14	0	0	0
Sticon	0	0	0	0	0	0
Traspi	1	7	21	22	2	3
SEDGES	0	1	2	2	2	1
Total Intermediate	90	202	290	397	321	105
Arispp	0	0	0	0	0	0
Cymexc	0	0	5	0	1	2
Lousim	5	7	0	0	0	0
Renalt	0	0	0	0	0	0
Total Unpalatable	5	7	5	1	1	2
Other	0	0	0	0	0	0
Total	235	420	519	473	387	148

Table 5.22 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the late 7 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	9/11/93	25/11/93	6/12/93	3/1/94	2/2/94	1/3/94	18/4/94
Andapp	0	2	2	0	1	0	1
Brabri	0	0	0	0	0	0	0
Braser	143	172	85	61	43	32	17
Ctecon	65	0	1	0	0	0	0
Cynspp	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0
Digtri	0	1	0	0	0	0	0
Dihamp	49	47	47	66	120	116	19
Eracap	1	3	14	14	11	12	5
Eulvil	83	157	191	155	68	50	19
Hetcon	25	38	48	23	51	42	21
Hyphir	8	3	0	5	1	17	9
Moncer	12	14	8	2	4	7	15
Setnig	13	35	11	9	2	1	7
Setsph	0	0	0	0	0	0	0
Thetri	174	240	290	592	603	542	578
Trileu	44	64	92	144	154	164	151
Total Palatable	618	775	791	1073	1057	982	840
Allsem	135	156	177	329	308	211	128
Digmon	2	2	2	8	15	3	5
Eracur	11	0	0	0	0	0	0
Erapla	0	0	0	0	0	0	0
Erarac	7	7	4	13	5	5	3
Eraspp	0	1	2	2	2	0	0
Harfal	0	0	0	0	0	0	0
Melner	4	4	5	9	9	9	0
Miccaf	4	0	0	0	0	7	3
Paneck	1	0	2	0	0	0	0
Pannat	2	51	159	110	55	49	36
Sticon	0	0	0	0	0	0	0
Traspi	7	11	27	35	22	87	106
SEDGES	2	4	1	0	3	2	8
Total Intermediate	174	237	379	505	418	372	289
Arispp	0	9	13	3	31	0	4
Cymexc	0	24	47	104	93	58	64
Lousim	28	4	4	34	6	8	11
Renalt	10	0	0	0	0	0	0
Total Unpalatable	38	36	64	141	130	66	79
Other	0	0	1	0	0	0	0
Total	830	1049	1234	1719	1606	1421	1208

Table 5.23 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the late 10 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	9/11/93	25/11/93	6/12/93	3/1/94	2/2/94	1/3/94	18/4/94
Andapp	5	1	2	1	0	0	1
Brabri	0	0	0	0	0	0	0
Braser	207	189	215	145	71	55	31
Ctecon	0	0	7	0	0	0	0
Cynspp	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0
Digtri	0	0	0	0	0	0	0
Dihamp	40	33	37	28	6	24	1
Eracap	2	5	7	13	6	5	4
Eulvil	93	165	203	319	360	180	89
Hetcon	25	17	15	25	25	9	7
Hyphir	18	6	8	20	25	27	15
Moncer	3	11	1	3	8	1	3
Setnig	67	69	44	30	21	6	9
Setsph	0	0	0	0	0	0	0
Thetri	117	205	217	305	335	259	376
Trileu	31	34	68	61	105	47	61
Total Palatable	608	734	827	949	961	613	596
Allsem	252	319	362	637	539	518	493
Digmon	0	0	0	1	2	1	3
Eracur	3	0	0	0	0	0	0
Erapla	0	0	0	0	0	0	0
Erarac	4	2	21	33	14	17	4
Eraspp	0	1	0	0	0	0	0
Harfal	0	0	0	0	0	0	0
Melner	27	0	0	0	0	1	0
Miccaf	3	4	4	0	1	2	1
Paneck	0	0	0	0	0	0	0
Pannat	1	0	0	19	0	0	0
Sticon	0	0	0	0	0	0	0
Traspi	13	34	30	75	106	67	105
SEDGES	4	0	0	0	0	1	0
Total Intermediate	307	360	418	766	662	607	608
Arispp	0	0	0	1	0	0	0
Cymexc	0	16	12	7	39	6	40
Lousim	9	0	4	0	6	0	5
Renalt	0	24	17	3	3	4	3
Total Unpalatable	9	40	32	11	48	10	47
Other	0	1	0	0	2	0	1
Total	924	1134	1276	1726	1673	1230	1252

Table 5.24 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the late 13 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	9/11/93	25/11/93	6/12/93	3/1/94	2/2/94	1/3/94	18/4/94
Andapp	3	0	1	1	0	6	0
Brabri	0	0	0	0	0	0	0
Braser	133	92	71	34	25	19	7
Ctecon	0	0	0	0	0	0	0
Cynspp	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0
Digtri	0	0	0	0	0	0	0
Dihamp	34	7	13	1	1	1	1
Eracap	1	15	12	17	12	7	3
Eulvil	96	153	198	268	140	65	44
Hetcon	6	18	25	6	5	15	1
Hyphir	3	1	0	1	0	0	1
Moncer	6	1	1	0	1	6	0
Setnig	42	62	47	26	16	16	5
Setsph	0	0	0	0	0	0	1
Thetri	184	290	389	489	365	360	174
Trileu	24	23	35	48	42	40	3
Total Palatable	532	661	792	890	607	534	239
Allsem	223	271	422	545	420	350	218
Digmon	0	0	13	14	2	2	1
Eracur	2	0	0	0	0	0	0
Erapla	0	0	0	0	0	0	0
Erarac	12	8	8	10	7	1	1
Eraspp	0	2	1	0	1	0	0
Harfal	0	0	0	0	0	0	0
Melner	8	1	1	0	2	0	0
Miccaf	1	1	2	1	0	5	4
Paneck	0	0	0	0	0	0	0
Pannat	16	0	4	0	16	0	0
Sticon	3	0	0	0	0	0	0
Traspi	23	29	16	69	121	72	64
SEDGES	0	1	2	1	12	0	1
Total Intermediate	288	313	468	639	582	429	289
Arispp	0	4	11	0	3	21	8
Cymexc	0	14	11	11	11	36	33
Lousim	16	5	0	5	17	1	21
Renalt	2	16	28	0	0	0	0
Total Unpalatable	18	40	49	16	32	58	62
Other	0	1	0	1	0	0	0
Total	838	1015	1309	1547	1221	1022	591

Table 5.25 Amounts of all grass species available (kg DM ha^{-1}) during the 1993/94 grazing season for the late 16 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	9/11/93	25/11/93	6/12/93	3/1/94	2/2/94	1/3/94	18/4/94
Andapp	1	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0
Braser	130	90	58	33	35	8	7
Ctecon	2	0	0	0	0	0	0
Cynspp	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	0	0
Digtri	0	2	0	0	0	0	0
Dihamp	23	6	4	8	1	2	1
Eracap	3	3	2	5	5	3	0
Eulvil	45	82	78	42	37	18	5
Hetcon	11	4	6	4	4	8	1
Hyphir	8	0	0	3	1	7	1
Moncer	15	2	7	3	5	2	1
Setnig	48	37	42	23	9	6	3
Setsph	0	0	0	0	0	0	0
Thetri	286	437	495	636	367	371	154
Trileu	51	72	135	127	118	99	81
Total Palatable	622	734	825	883	582	526	255
Allsem	195	230	281	372	353	298	140
Digmon	0	6	7	3	6	4	0
Eracur	6	0	0	1	0	0	0
Erapla	0	0	0	0	0	0	0
Erarac	2	13	7	14	6	1	0
Eraspp	0	1	0	1	1	0	0
Harfal	0	0	0	0	0	0	0
Melner	0	1	0	0	0	0	0
Miccaf	1	0	0	0	0	2	5
Paneck	2	5	0	0	0	0	0
Pannat	2	5	8	10	11	11	15
Sticon	0	0	0	0	0	0	0
Traspi	31	28	53	71	57	137	90
SEDGES	1	1	4	5	4	1	2
Total Intermediate	240	290	358	477	438	454	252
Arispp	0	0	14	3	0	0	1
Cymexc	0	2	6	18	4	8	4
Lousim	5	0	0	1	0	1	0
Renalt	1	0	0	0	0	0	0
Total Unpalatable	6	3	20	22	4	10	5
Other	0	0	0	0	0	0	0
Total	868	1027	1203	1383	1024	990	512

Table 5.26 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the early 7 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	24/10/94	8/11/94	22/11/94	20/12/94	26/1/95	27/2/95	25/4/95
Andapp	0	0	0	0	0	0	0
Brabri	2	0	0	0	0	0	0
Braser	22	11	6	19	5	1	1
Ctecon	3	7	14	3	6	2	79
Cynspp	0	0	0	0	0	0	0
Digfla	1	3	10	10	2	0	0
Digtri	0	0	0	0	0	0	0
Dihamp	51	56	75	133	69	4	11
Eracap	1	0	4	0	0	0	0
Eulvil	8	18	25	68	108	56	133
Hetcon	3	5	18	30	35	21	32
Hyphir	17	19	15	15	28	9	40
Moncer	16	20	10	7	3	1	1
Setnig	6	8	12	8	0	0	0
Setsph	0	0	0	0	0	0	0
Thetri	38	79	138	171	180	313	115
Trileu	13	24	38	72	140	127	29
Total Palatable	181	250	365	536	574	534	440
Allsem	23	27	32	118	85	121	122
Digmon	0	0	0	0	0	0	0
Eracur	5	22	31	42	31	67	11
Erapla	0	0	0	0	10	0	6
Erarac	2	15	21	41	30	10	5
Eraspp	0	1	3	0	0	0	0
Harfal	0	0	0	0	0	0	0
Melner	2	5	1	0	0	0	0
Miccaf	1	0	0	0	3	0	0
Paneck	0	0	0	0	0	0	0
Pannat	5	1	3	1	13	0	0
Sticon	0	0	0	0	0	0	0
Traspi	22	50	102	214	111	197	255
SEDGES	0	1	0	1	1	1	3
Total Intermediate	61	122	193	416	282	396	402
Arispp	0	0	0	0	5	0	0
Cymexc	0	0	0	0	0	0	0
Lousim	4	5	4	6	40	8	6
Renalt	62	100	109	163	279	269	212
Total Unpalatable	65	105	113	169	323	277	217
Other	0	0	0	0	0	1	0
Total	307	477	671	1122	1180	1207	1060

Table 5.27 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the early 10 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	24/10/94	8/11/94	22/11/94	20/12/94	26/1/95	27/2/95	25/4/95
Andapp	0	0	0	0	1	0	0
Brabri	13	2	6	3	1	0	3
Braser	21	9	10	12	18	2	4
Ctecon	1	2	7	10	3	0	0
Cynspp	0	0	0	0	0	0	0
Digfla	0	0	1	0	0	0	0
Digtri	0	0	0	0	0	0	0
Dihamp	52	47	59	96	26	10	8
Eracap	2	1	8	0	0	0	0
Eulvil	13	28	31	34	121	146	172
Hetcon	2	18	28	16	15	37	17
Hyphir	45	44	73	61	40	15	20
Moncer	17	22	18	22	2	0	4
Setnig	0	0	0	0	0	0	0
Setsph	0	0	0	0	0	0	0
Thetri	29	90	96	150	248	234	139
Trileu	9	41	35	102	102	80	74
Total Palatable	203	305	371	509	576	525	441
Allsem	56	75	141	256	333	419	325
Digmon	0	0	0	0	0	0	0
Eracur	6	20	23	13	57	56	14
Erapla	0	0	0	0	13	0	10
Erarac	3	16	30	40	27	9	13
Eraspp	0	0	1	0	0	0	0
Harfal	0	0	0	0	0	0	0
Melner	4	1	9	0	1	0	7
Miccaf	0	1	0	1	0	31	0
Paneck	0	1	0	0	0	0	0
Pannat	3	1	1	2	0	0	0
Sticon	0	0	0	0	0	0	0
Traspi	6	47	51	89	154	61	129
SEDGES	0	1	3	9	1	8	4
Total Intermediate	76	163	259	410	585	586	502
Arispp	0	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0	0
Lousim	3	3	1	4	9	7	18
Renalt	10	16	18	16	37	30	46
Total Unpalatable	13	19	19	20	46	36	64
Other	0	0	0	0	0	0	0
Total	292	488	649	939	1207	1148	1007

Table 5.28 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the early 13 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	24/10/94	8/11/94	22/11/94	20/12/94	26/1/95	27/2/95	25/4/95
Andapp	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0
Braser	43	30	15	13	24	4	5
Ctecon	2	2	1	0	5	0	2
Cynspp	0	0	0	0	0	0	0
Digfla	1	3	8	·4	3	0	0
Digtri	0	0	0	0	0	0	0
Dihamp	32	43	16	18	6	1	5
Eracap	3	1	1	0	1	0	0
Eulvil	2	21	23	19	7	9	5
Hetcon	3	4	15	11	2	0	0
Hyphir	12	10	8	4	15	16	1
Moncer	24	10	0	6	2	0	1
Setnig	1	0	0	0	2	0	0
Setsph	0	0	0	0	0	0	0
Thetri	28	86	134	196	64	46	26
Trileu	22	70	130	283	260	189	110
Total Palatable	173	280	352	555	389	265	156
Allsem	57	108	146	237	288	259	103
Digmon	0	0	4	·0	3	0	0
Eracur	5	27	21	45	13	7	3
Erapla	0	0	0	0	4	0	5
Erarac	0	6	6	5	5	1	2
Eraspp	0	1	1	0	0	0	1
Harfal	0	0	0	0	0	1	0
Melner	0	6	6	0	0	4	0
Miccaf	1	1	0	3	4	0	9
Paneck	2	1	4	0	0	0	0
Pannat	1	1	0	1	1	0	0
Sticon	0	0	0	0	0	0	0
Traspi	6	16	67	61	126	167	218
SEDGES	0	0	1	1	6	12	1
Total Intermediate	73	166	256	353	450	450	340
Arispp	0	0	0	·0	0	0	0
Cymexc	0	0	0	0	0	0	0
Lousim	3	8	2	15	20	9	18
Renalt	61	97	110	203	252	327	290
Total Unpalatable	64	105	112	219	272	336	308
Other	0	0	2	0	0	0	0
Total	310	551	722	1127	1112	1051	804

Table 5.29 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the early 16 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	24/10/94	8/11/94	22/11/94	20/12/94	26/1/95	27/2/95	25/4/95
Andapp	0	1	1	0	0	0	0
Brabri	0	0	0	0	0	0	0
Braser	53	16	18	21	23	4	12
Ctecon	3	8	24	7	0	0	1
Cynspp	0	0	0	0	0	0	0
Digfla	0	0	2	.2	2	1	0
Digtri	2	0	0	0	0	0	0
Dihamp	7	5	3	6	7	0	17
Eracap	1	1	15	1	1	0	0
Eulvil	43	78	110	194	239	260	158
Hetcon	4	26	15	38	6	11	18
Hyphir	1	3	4	4	37	5	22
Moncer	11	2	3	1	3	0	0
Setnig	54	71	92	53	22	10	3
Setsph	0	0	2	0	0	0	0
Thetri	49	73	155	196	179	186	135
Trileu	13	17	33	45	74	96	46
Total Palatable	242	302	477	568	592	574	413
Allsem	68	112	147	279	357	416	306
Digmon	0	0	0	.0	0	0	0
Eracur	1	5	1	11	8	39	14
Erapla	0	0	0	0	0	0	0
Erarac	0	3	3	4	1	0	1
Eraspp	0	0	4	0	2	5	1
Harfal	2	2	0	9	1	12	14
Melner	0	6	7	0	1	0	0
Miccaf	2	1	13	16	10	21	17
Paneck	0	4	1	0	0	0	0
Pannat	2	0	0	5	5	1	0
Sticon	0	0	0	0	0	0	0
Traspi	0	8	32	36	58	90	84
SEDGES	0	0	1	3	3	3	4
Total Intermediate	76	142	210	363	446	587	442
Arispp	0	0	0	.0	0	0	0
Cymexc	0	0	0	0	0	0	0
Lousim	2	4	10	27	19	34	20
Renalt	1	3	6	2	0	9	0
Total Unpalatable	2	7	17	29	19	44	21
Other	0	0	0	0	0	0	0
Total	320	451	704	960	1057	1204	876

Table 5.30 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the late 7 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	14/11/94	28/11/94	13/12/94	25/1/95	28/2/95	25/4/95
Andapp	0	0	0	0	0	0
Brabri	8	0	10	3	0	8
Braser	66	12	8	9	1	3
Ctecon	11	3	4	0	0	11
Cynspp	0	0	0	0	0	0
Digfla	2	2	1	.0	0	0
Digtri	0	0	0	0	0	0
Dihamp	82	95	103	25	13	10
Eracap	2	2	0	0	0	0
Eulvil	48	82	112	301	263	285
Hetcon	18	24	38	59	45	4
Hyphir	20	38	25	36	15	23
Moncer	21	16	28	21	1	6
Setnig	0	0	0	1	0	0
Setsph	0	0	0	0	0	0
Thetri	164	195	309	452	552	426
Trileu	11	11	20	47	63	32
Total Palatable	453	479	660	954	954	809
Allsem	79	155	177	387	243	348
Digmon	0	0	0	.0	0	0
Eracur	6	8	5	38	40	22
Erapla	0	0	0	1	0	3
Erarac	4	6	6	3	1	1
Eraspp	2	12	0	0	0	1
Harfal	0	0	0	0	0	0
Melner	29	21	30	14	0	0
Miccaf	0	4	0	0	0	1
Paneck	7	2	0	0	0	0
Pannat	18	22	61	26	35	45
Sticon	0	0	0	0	0	0
Traspi	21	63	46	44	105	133
SEDGES	1	0	1	1	48	1
Total Intermediate	167	292	325	513	472	554
Arispp	0	0	0	.0	0	0
Cymexc	0	0	0	0	0	0
Lousim	11	12	29	23	17	19
Renalt	3	2	7	3	8	16
Total Unpalatable	14	14	36	26	24	35
Other	0	0	0	0	0	0
Total	634	786	1020	1494	1450	1398

Table 5.31 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the late 10 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	14/11/94	28/11/94	13/12/94	25/1/95	28/2/95	25/4/95
Andapp	2	0	0	0	0	0
Brabri	5	41	73	45	16	27
Braser	51	22	25	3	6	11
Ctecon	29	45	18	29	30	21
Cynspp	0	0	0	0	0	0
Digfla	1	11	2	1	0	0
Digtri	0	0	0	14	0	0
Dihamp	54	31	13	20	10	0
Eracap	2	3	2	0	0	0
Eulvil	16	31	47	113	98	80
Hetcon	15	29	4	44	20	5
Hyphir	22	46	22	100	32	94
Moncer	3	1	1	0	1	0
Setnig	100	135	106	100	52	29
Setsph	4	0	0	0	14	0
Thetri	158	165	254	429	345	354
Trileu	73	174	153	147	160	120
Total Palatable	535	734	719	1044	783	740
Allsem	74	132	180	242	226	170
Digmon	0	0	0	0	0	0
Eracur	21	46	42	50	115	72
Erapla	6	0	0	3	0	15
Erarac	3	9	2	2	2	1
Eraspp	5	0	0	0	0	0
Harfal	0	0	5	1	16	26
Melner	0	5	2	6	0	0
Miccaf	0	0	1	0	1	0
Paneck	3	0	0	0	0	0
Pannat	22	20	67	31	70	40
Sticon	0	0	0	0	1	0
Traspi	56	77	120	143	136	221
SEDGES	4	5	3	5	14	7
Total Intermediate	194	294	421	482	581	553
Arispp	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0
Lousim	1	20	42	20	4	19
Renalt	14	25	16	16	40	31
Total Unpalatable	14	45	59	36	44	50
Other	2	0	0	0	0	0
Total	746	1073	1199	1563	1408	1344

Table 5.32 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the late 13 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	14/11/94	28/11/94	13/12/94	25/1/95	28/2/95	25/4/95
Andapp	0	0	0	0	0	0
Brabri	3	0	2	0	0	0
Braser	56	29	16	7	4	3
Ctecon	7	4	13	0	0	4
Cynspp	0	0	0	0	0	0
Digfla	3	6	1	0	0	0
Digtri	0	0	0	0	0	0
Dihamp	212	272	362	113	30	30
Eracap	1	2	3	0	5	0
Eulvil	27	39	33	76	84	84
Hetcon	9	25	17	2	16	9
Hyphir	35	97	72	166	120	151
Moncer	30	24	52	13	68	1
Setnig	0	6	0	0	0	0
Setsph	0	0	0	0	0	0
Thetri	213	271	338	637	523	533
Trileu	9	8	32	25	48	11
Total Palatable	605	782	942	1039	897	827
Allsem	34	35	77	111	162	126
Digmon	0	0	0	0	0	0
Eracur	23	37	35	64	93	30
Erapla	0	3	0	8	8	6
Erarac	14	14	17	13	11	4
Eraspp	1	3	0	0	0	0
Harfal	0	0	0	0	1	0
Melner	17	6	13	2	0	4
Miccaf	0	0	0	0	0	1
Paneck	2	0	0	0	0	0
Pannat	13	20	28	4	6	6
Sticon	0	0	0	0	0	0
Traspi	64	46	129	126	121	132
SEDGES	0	0	1	0	10	1
Total Intermediate	168	164	300	329	412	310
Arispp	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0
Lousim	1	43	40	40	25	29
Renalt	3	10	8	6	11	29
Total Unpalatable	5	53	48	45	36	57
Other	1	0	0	0	7	0
Total	779	1000	1289	1414	1353	1194

Table 5.33 Amounts of all grass species available (kg DM ha^{-1}) during the 1994/95 grazing season for the late 16 sheep ha^{-1} treatment. A full list of species names and abbreviation is tabled in Appendix 2

	14/11/94	28/11/94	13/12/94	25/1/95	28/2/95	25/4/95
Andapp	0	0	0	0	0	0
Brabri	7	1	9	0	0	0
Braser	61	8	6	6	3	3
Ctecon	2	5	8	0	1	9
Cynspp	0	0	0	0	0	0
Digfla	7	8	2	0	0	0
Digtri	0	0	0	2	0	0
Dihamp	174	238	255	82	17	22
Eracap	6	1	1	0	0	0
Eulvil	45	53	48	142	180	239
Hetcon	20	25	31	39	24	12
Hyphir	20	46	25	26	9	12
Moncer	19	22	96	17	7	9
Setnig	6	2	0	0	0	0
Setsph	0	0	1	0	0	0
Thetri	170	212	263	412	462	218
Trileu	29	56	57	125	105	93
Total Palatable	566	677	802	850	809	617
Allsem	122	122	138	320	238	149
Digmon	0	0	0	0	0	0
Eracur	1	10	37	43	11	13
Erapla	0	0	0	0	0	0
Erarac	22	33	30	23	14	5
Eraspp	6	5	0	0	1	0
Harfal	0	0	0	0	3	0
Melner	14	16	29	0	0	2
Miccaf	0	0	0	0	0	0
Paneck	1	3	0	0	0	0
Pannat	1	2	1	0	0	0
Sticon	0	0	0	0	0	0
Traspi	24	24	65	98	103	132
SEDGES	0	0	3	2	3	0
Total Intermediate	192	214	303	486	375	301
Arispp	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0
Lousim	3	3	5	7	8	6
Renalt	0	1	3	2	8	5
Total Unpalatable	3	4	9	9	16	11
Other	0	0	0	0	0	0
Total	761	895	1114	1345	1200	929

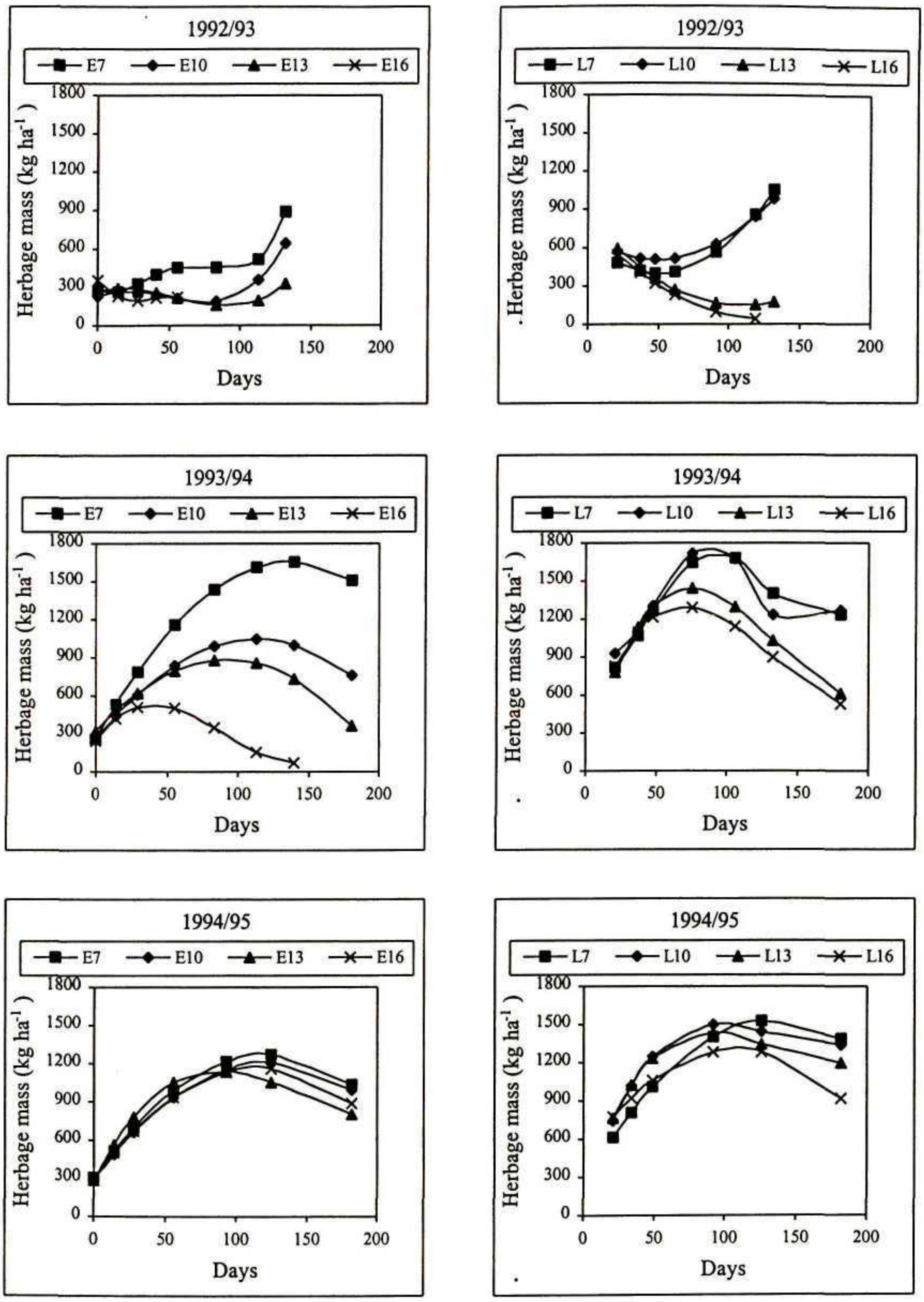


Figure 5.1 Herbage availability (kg DM ha^{-1}) throughout the season for each treatment during each of the first three seasons for the early (E) and late (L) times of stocking and the 7, 10, 13 and 16 sheep ha^{-1} stocking rates

CHAPTER 6

TRIAL 1
THE EFFECT OF THE INTERACTION BETWEEN VELD QUALITY AND QUANTITY ON SHEEP PERFORMANCE

6.1 Sheep performance

Sheep performance is the result of a complex set of interactions involving the environment, the sheep and the feed. Of interest in this study was the effect of grazing management treatments on sheep performance. The management variables applied influenced only the grazing (available herbage), both in terms of quality and quantity within a given season. The investigation of the factors influencing sheep performance included examination of the intra-seasonal variations in quality and quantity with a view to developing predictive models describing sheep performance based specifically on the data collected in the present study. The impact of the treatments on quality and quantity has been presented in Chapters 4 and 5 respectively. The effect of the variations in quality and quantity are, firstly, examined separately, and then together. Observations on the impact of individual species availability on sheep performance are included. Progressive average daily gain (PADG) has been used as the measure of sheep performance (dependant variable) as it is a measure of average daily gain sheep^{-1} day^{-1}. As such it can be directly related to quality and available herbage day^{-1} over the season.

6.2 Effect of veld quality and quantity on sheep performance considering each treatment separately

The quality of the forage available to the sheep at the beginning of the season varied substantially between the early and late times of stocking (Table 4.5). The effects of the variations in quality over the season, both normal seasonal declines as well as treatment-induced quality variations have been presented in Figures 4.1 and 4.2.

The quantity of the forage available to the sheep at the beginning of the season also varied substantially between the early and late times of stocking (Table 5.3). The variations in quantity over the season, both normal seasonal accumulation of herbage as well as treatment-induced quantity variations can be examined in Figure 5.1.

6.2.1 Effect of quality and quantity at time of stocking on sheep performance

The effects of initial quality on sheep performance over the season were examined using regression analysis. No clear cause and effect relations were established between PADG and any of the quality parameters measured. Attempts at developing multiple regression models to describe sheep performance in terms of combinations of quality factors and treatments also failed to yield significant relations. Examination of the data revealed that the stocking rate treatments and the variations between seasons caused wide fluctuations in the sheep performance, which partially masked the effect of time of stocking. Initial quality parameters can thus not be used alone in any predictive sheep performance model.

The effects of stocking rate on sheep performance and the variations in initial herbage between seasons masked the effects of variations in initial herbage available to, or selected by sheep on sheep performance over the season. In a similar manner to initial quality, initial quantity can thus not be used alone in a predictive sheep performance model.

6.2.2 Effect of treatment-induced intra-seasonal quality and quantity variations on sheep performance

The sheep performance, quality and quantity data were all collected in a time sequence during each season as described in Chapter 2. This complicates examining the data in an attempt to develop cause and effect relations between sheep performance and quality and quantity. The analysis of time series data is complicated and it seems that not all researchers and statisticians in the biological fields have reached consensus in dealing with such data. In this study, an approach outlined by Ezekiel & Fox (1959) has been adopted. The data was interpreted with caution and the possibility of auto-correlation influencing the interpretation of the analyses was kept in mind. Inspection of the data presented previously revealed that the stocking rate and time of stocking treatments had a substantial effect on the amount of herbage available during the season (Table 5.2), as well as the quality selected and available (Tables 4.1 to 4.4).

6.2.2.1 Examination of the effects of the amount of herbage available, the crude protein content and the *in vitro* digestible organic matter content of the herbage on sheep performance

The relations between sheep performance (PADG), quantity (kg DM ha^{-1}) and quality (% CP and % IVDOM over the season) were examined for fistula samples as well as the clipped samples using regression analysis. Each parameter was examined separately and then combined using forward stepwise multiple regression in an attempt to develop cause and effect relations. Each treatment was examined separately for each of the first three seasons to isolate the unique quantity and quality conditions induced by each treatment. Seasons were kept separate because of differing environmental conditions resulting in substantial variations in veld productivity. It appears that sheep performance is dependent on a complex interaction of variables, with different variables limiting performance at different times and on different treatments.

Examination of the regression formulas in Tables 6.1 to 6.5 reveal some interesting trends. The mean amount of available herbage (kg DM ha^{-1}) was clearly limiting in certain treatments (Table 6.1). These were in all cases heavy stocking rate treatments (1992/93 early 13 and 16, 1992/93 late 16, 1993/94 early 16, and 1993/94 late 13 and 16). In the remainder of the treatments PADG was negatively related to the mean amount of herbage available. It seems that there may be a threshold amount of herbage available, below which sheep performance is limited. The threshold value is likely to be related to species composition, structure and quality of available herbage. No attempt was thus made to estimate the threshold value of available herbage alone. Not all of the regression relations were significant. This suggests that sheep performance is dependent on other factors besides quantity. Examination of the mean amount of forage available during each season for each treatment (Table 5.5) and per sheep (Table 5.6) did not clarify the role of forage quantity in determining livestock performance. In particular, the mean amount of forage available per sheep for each treatment over each season indicated a decreasing linear response to stocking rate. However, the response of stocking rate on sheep performance was not linear (Figure 3.1). Also, the sheep on the early time of stocking treatments had less forage available throughout the season, but in general their mass gains were greater than those on the late time of stocking treatments. These data reinforce the complexity of the factors affecting livestock performance on veld.

The quality (CP and IVDOM) of the selected herbage was generally positively related to sheep performance (Tables 6.2 & 6.3). Again, not all of the regressions were significant, implying that quality is not the main factor determining sheep performance.

With one exception, the quality (CP and IVDOM) of the available herbage was positively related to the sheep performance (Tables 6.4 & 6.5). The exception was the CP of the 1992/93 late 13 treatment that was negatively related to sheep performance. Again the regression was not significant.

The relations between sheep performance and all the quantity and quality parameters were examined for all combinations of quantity and selected or available herbage. Strong relations were established for all treatments. In most cases, available herbage in combination with available CP and IVDOM showed the strongest relations with sheep performance. However, the variation in the relations between treatments and seasons was quite large and inconsistent. It also appeared that the more complex procedure of sampling selected herbage by means of sheep fistulated at the oesophagus yielded a less precise measure than that of sampling available herbage by clipping.

6.3 Effect of quality and quantity on sheep performance with all treatments grouped together

It would be convenient to establish a generalised relation in the form of a multiple regression formula describing sheep performance in terms of available herbage and the quality thereof. This would make it possible, by means of estimating veld production over a season, potential sheep intake and quality of available herbage during the season, to describe potential sheep performance on veld with reasonable accuracy. The approach would allow the impact of management (stocking rate and time of stocking) to be quantified for a given situation, thus enhancing decision making and planning for optimum sheep performance.

Examination of data grouped from all treatments and seasons revealed that this would not be an easy task. The impact of herbage availability for example, differs depending on the amount of herbage. At low levels of herbage availability, it is a factor limiting sheep production, with sheep performance positively related to increasing herbage availability. At higher levels of herbage availability, sheep performance is negatively related to increasing herbage availability. Grouping the data from treatments and seasons masks this effect.

From Tables 6.2 to 6.5, it is obvious that sheep performance is positively related to quality. However, the magnitude of the relation changes between treatments and seasons. The interaction between quantity and quality is also important and variations in the multiple regression formulas obtained demonstrated the non-feasibility of grouping the data.

It seems that the development of a simple model to predict sheep performance in terms of available quantity and quality is not feasible based on the current data.

6.4 Effect of variations in availability of individual grass species on sheep performance

The patterns of availability of individual species and species groups for each treatment during each season are presented in Tables 5.10 to 5.33. Absolute comparisons between treatments and season are difficult because of the variations in species productivity between treatments. Examination of the data did however, reveal some interesting trends.

In those treatments where sheep performance was positively related to amount of available herbage (1992/93 early 13 and 16, 1992/93 late 16, 1993/94 early 16, and

1993/94 late 13 and 16), the amount of palatable material declined during the season. The amount of material of intermediate palatability either declined in a similar manner to the palatable material, or first increased and then declined. The amount of unpalatable material increased where there was enough to measure accurately. This indicates that the palatability of the species also played a role in determining sheep performance.

Considering the treatments where available herbage was not a limiting factor, it appears that the factors affecting sheep performance are extremely complex. Apart from the interactions between quantity and quality discussed previously, it is obvious that the availability of individual species also plays a major role in determining sheep performance potential. Examination of the data reveals that there are about fourteen species that consistently contribute significantly to the available herbage. The variations in amounts of each species available at the beginning of each season, the inherent variations in growth rates between species and the treatment-induced variations in amounts of available herbage on a species basis make the patterns of species availability extremely complex. This, coupled with the quality differences and palatability differences between species make the cause and effect relations between species availability and sheep performance extremely difficult to isolate and describe.

6.5 Discussion

The data presented in Chapters 3, 4 and 5 gives unique insight into the impact of stocking rate and time of stocking on the response patterns of herbage availability, species availability, quality availability, quality selected and sheep performance. Prediction of sheep performance based on the measured parameters is extremely complex, and no simple cause and effect relations could be isolated that would be widely applicable. It seems that each treatment and season is unique and that any of a number of factors may negatively impact sheep performance. In particular, the availability of individual veld grass species seems to play a major role in influencing sheep performance. Observation, reinforced by examining sheep performance in conjunction with Tables 5.9 to 5.32, revealed that when the sheep started to graze *Alloteropsis semialata*, performance tended to decrease. Usually the sheep avoided *Alloteropsis semialata* until the more palatable species had been grazed short. This phenomenon was, however, apparently unrelated to total herbage availability, quality availability or the quality of herbage selected by fistulated sheep. It may be that certain physical characteristics of the particular species resulted in lower intake independent of any of the measured parameters. The difficulty of interpreting this phenomenon and applying it in a model, is that each situation is different and a different (unknown) species may replace *Alloteropsis semialata* as the "threshold" species in any other situation.

The herbage quantity and quality data presented is detailed in terms of quantity of forage available, both in terms of individual species and total forage. The structure of the herbage was not addressed in this study, which may be a shortcoming. O'Reagain (1996b) found that sward structure was an important factor determining livestock performance. In terms of herbage quality, the data collected was less complete. Laboratory facilities as well as costs limited the quality analyses to CP and IVDOM. While these two measures are important factors in determining livestock performance, there are other factors that may also play an important role, particularly in a multi-species sward. In particular, the role of fibre (neutral detergent and acid detergent fibre) may be critical in determining intake of individual grass species (van Soest 1983). While the availability of each species was well quantified during the season, the associated quality of each species was unknown (including the variations in quality of each species over time during the season.

The uniqueness of the interaction of livestock with the multi-species veld found in the sourveld regions of Southern Africa limit the possibilities of developing a model to predict livestock performance with any degree of accuracy based on the data collected in this study (bearing mind the lack of detailed quality analyses and structure profile of the herbage).

These results are in broad agreement with (O'Reagain 1996a; 1996b) who found that species composition and sward structure were important determinants of animal production on sourveld. O'Reagain (1996b) stated that an optimum species composition and sward structure could not be specified, as they were dependent on each other, as well as on the season and the animal species involved.

Table 6.1 Relations between PADG (Y) and available herbage (kg DM ha^{-1}) (X) for all treatments over the first three seasons

Season	Time	Stocking rate	Regression equation (PADG (g) is the response variate)	Significance level	R_a^2
1992/93	Early	7	255-0.4839X	P<0.001	85.8
1992/93	Early	10	57-0.001X	P=0.994	-
1992/93	Early	13	-26+0.44X	P=0.148	24.3
1992/93	Early	16	-33+0.338X	P=0.201	45.8
1992/93	Late	7	94-0.073X	P=0.230	12.6
1992/93	Late	10	39-0.000001X	P=0.910	-
1992/93	Late	13	39-0.0124X	P=0.483	-
1992/93	Late	16	1.13+0.0423X	P<0.001	93.3
1993/94	Early	7	97-0.0252X	P<0.001	92.3
1993/94	Early	10	83-0.0388X	P<0.01	81.7
1993/94	Early	13	60-0.027X	P<0.05	53.0
1993/94	Early	16	23+0.0592X	P=0.185	18.4
1993/94	Late	7	139-0.059X	P<0.05	64.2
1993/94	Late	10	61-0.0005X	P=0.974	-
1993/94	Late	13	69+0.0033X	P=0.926	-
1993/94	Late	16	14.5+0.0343X	P=0.335	2.3
1994/95	Early	7	174-0.0878X	P<0.001	93.3
1994/95	Early	10	125-0.0541X	P<0.001	93.0
1994/95	Early	13	129-0.0612X	P<0.05	71.5
1994/95	Early	16	146-0.0716X	P<0.01	91.2
1994/95	Late	7	157-0.08X	P<0.01	94.9
1994/95	Late	10	201-0.1022X	P<0.05	76.6
1994/95	Late	13	108-0.0429X	P<0.05	70.7
1994/95	Late	16	121-0.0656X	P=0.088	56.8

Table 6.2 Relations between PADG (Y) and % CP collected from fistula samples (X) for all treatment over the first three years

Season	Time	Stocking rate	Regression equation (PADG (g) is the response variate)	Significance level	R_a^2
1992/93	Early	7	-64+10.4X	P=0.364	-
1992/93	Early	10	-134+13.5X	P<0.01	79.2
1992/93	Early	13	-211+20.2X	P=0.249	10.4
1992/93	Early	16	-177+15.8X	P<0.05	96.8
1992/93	Late	7	129-6.5X	P=0.709	-
1992/93	Late	10	39+0.001X	P=0.641	-
1992/93	Late	13	30.9+40X	P=0.840	-
1992/93	Late	16	-31+3.4X	P=0.145	31.1
1993/94	Early	7	7.5+5.08X	P<0.001	95.5
1993/94	Early	10	9.9+3.5X	P=0.121	29.2
1993/94	Early	13	-19.9+5.25X	P<0.001	99.4
1993/94	Early	16	-42.5+6.21X	P<0.05	66.6
1993/94	Late	7	276-21.7X	P=0.179	19.4
1993/94	Late	10	-102+13.6X	P<0.05	56.3
1993/94	Late	13	-216+25.7X	P<0.05	54.7
1993/94	Late	16	-177+19.5X	P<0.001	98.5
1994/95	Early	7	-157+21.7X	P<0.001	96.6
1994/95	Early	10	-221+23X	P<0.001	98.8
1994/95	Early	13	-164+17.1X	P<0.001	99.0
1994/95	Early	16	-128+16.1X	P=0.301	7.6
1994/95	Late	7	-334+34X	P<0.05	73.2
1994/95	Late	10	-374+34.3X	P<0.01	95.4
1994/95	Late	13	-68+10.2X	P<0.01	95.6
1994/95	Late	16	-478+42.1X	P<0.01	91.0

Table 6.3 Relations between PADG (Y) and % IVDOM collected from fistula samples (X) for all treatments over the first three seasons

Season	Time	Stocking rate	Regression equation (PADG (g) is the response variate)	Significance level	R_a^2
1992/93	Early	7	-232+5.49X	P<0.001	98.7
1992/93	Early	10	-31.5+1.8X	P<0.05	69.5
1992/93	Early	13	-68.7+2.9X	P<0.001	86.7
1992/93	Early	16	-133+3.3X	P<0.01	97.4
1992/93	Late	7	-95+3.3X	P<0.05	67.6
1992/93	Late	10	39+0.0001X	P=0.701	-
1992/93	Late	13	24.5+0.23X	P=0.491	-
1992/93	Late	16	-39+1.1X	P<0.001	92.7
1993/94	Early	7	-44.6+2.1X	P<0.001	96.3
1993/94	Early	10	-23.5+1.4X	P<0.001	97.9
1993/94	Early	13	-29.9+1.35X	P<0.001	99.4
1993/94	Early	16	-49.3+1.8X	P<0.001	98.4
1993/94	Late	7	-229+5.7X	P<0.05	67.1
1993/94	Late	10	-17.5+1.5X	P<0.05	62.0
1993/94	Late	13	-374+8.8X	P<0.001	91.1
1993/94	Late	16	-100.8+2.96X	P<0.001	98.5
1994/95	Early	7	-185+5.2X	P<0.01	88.2
1994/95	Early	10	-216+5.3X	P<0.001	98.8
1994/95	Early	13	-20+1.93X	P=0.1	41.4
1994/95	Early	16	-85+3.23X	P=0.075	48.4
1994/95	Late	7	-505+10.9X	P<0.01	92.9
1994/95	Late	10	-198+5X	P<0.05	80.4
1994/95	Late	13	-82+2.7X	P<0.01	96.7
1994/95	Late	16	-52+2X	P=0.12	47.8

Table 6.4 Relations between PADG (Y) and % CP collected from clipped herbage samples (X) for all treatments over the first three seasons

Season	Time	Stocking rate	Regression equation (PADG (g) is the response variate)	Significance level	R_a^2
1992/93	Early	7	-93+19.3X	P<0.001	99.0
1992/93	Early	10	-74+11.7X	P=0.192	17.5
1992/93	Early	13	-29.6+10.8X	P<0.01	83.5
1992/93	Early	16	-46.4+9.8X	P<0.05	89.1
1992/93	Late	7	-220+32X	P<0.001	93.9
1992/93	Late	10	39+0.0001X	P=0.701	-
1992/93	Late	13	57-2.7X	P=0.257	9.5
1992/93	Late	16	-40.8+6.4X	P<0.01	89.4
1993/94	Early	7	43+3.5X	P<0.001	92.7
1993/94	Early	10	19.9+3.9X	P<0.001	93.1
1993/94	Early	13	21.5+2.4X	P<0.001	93.2
1993/94	Early	16	-30.8+7.6X	P<0.001	98.4
1993/94	Late	7	-5.7+9.8X	P<0.001	89.1
1993/94	Late	10	41.8+2.9X	P<0.05	36.2
1993/94	Late	13	0.6+10.8X	P<0.001	96.9
1993/94	Late	16	-28.7+11.4X	P<0.001	97.9
1994/95	Early	7	8.7+10.5X	P<0.001	96.4
1994/95	Early	10	24.2+6.6X	P<0.001	96.3
1994/95	Early	13	13.5+7.1X	P<0.001	96.6
1994/95	Early	16	12.8+8.1X	P<0.001	97.4
1994/95	Late	7	-33.4+15X	P<0.01	95.7
1994/95	Late	10	-75+20.9X	P<0.01	96.2
1994/95	Late	13	7+7.2X	P<0.01	96.5
1994/95	Late	16	4.2+6.7X	P=0.251	20.2

Table 6.5 Relations between PADG (Y) and % IVDOM collected from clipped herbage samples (X) for all treatments over the first three seasons

Season	Time	Stocking rate	Regression equation (PADG (g) is the response variate)	Significance level	R_a^2
1992/93	Early	7	-97+3.7X	P<0.01	77.8
1992/93	Early	10	-73.5+2.4X	P<0.05	47.0
1992/93	Early	13	-21+2.2X	P<0.05	68.2
1992/93	Early	16	-121+3.5X	P<0.01	98.0
1992/93	Late	7	-128+3.2X	P<0.05	42.2
1992/93	Late	10	39+0.0001X	P=701	-
1992/93	Late	13	34.3+0.035X	P=0.839	-
1992/93	Late	16	-37.8+0.94X	P<0.001	97.3
1993/94	Early	7	13+1.1X	P<0.001	96.9
1993/94	Early	10	-30.5+1.6X	P<0.001	99.2
1993/94	Early	13	1.6+0.78X	P<0.001	99.4
1993/94	Early	16	-36+1.5X	P<0.001	98.4
1993/94	Late	7	-42+2.3X	P<0.001	90.3
1993/94	Late	10	27.5+0.7X	P<0.05	45.0
1993/94	Late	13	-30.5+2.2X	P<0.001	98.1
1993/94	Late	16	-52+2.1X	P<0.001	98.5
1994/95	Early	7	-77+3.8X	P<0.001	98.9
1994/95	Early	10	-18.9+2.1X	P<0.001	97.7
1994/95	Early	13	-18.7+2X	P<0.001	98.9
1994/95	Early	16	-23+2.2X	P<0.001	97.8
1994/95	Late	7	-99.6+3.6X	P<0.01	96.6
1994/95	Late	10	-94+3.9X	P<0.01	96.2
1994/95	Late	13	3.8+1.1X	P<0.01	96.6
1994/95	Late	16	-28.9+1.7X	P<0.05	81.6

CHAPTER 7

TRIAL 1.

EFFECT OF TIME OF STOCKING AND STOCKING RATE ON SPECIES COMPOSITION AND VELD VIGOUR

7.1 Effect of treatments on veld species composition

The proportional species composition of the veld in each paddock was determined by means of the nearest plant-point technique. A minimum of 300 points per paddock were recorded using a wheel point apparatus. Both blocks were surveyed during the first season, 1992/93. Due to the changes in treatment layout affecting the early 7 and 16 treatments in block 1 after the first season, the new paddocks for these two treatments were surveyed during the early part of the next grazing season for that block, namely 1994/95. All paddocks in block 1 were surveyed again during the latter part of the 1996/97 season. All paddocks in block 1 had thus been subjected to three grazing seasons, with the exception of early 7 and 16, which had been subjected to two grazing seasons. The paddocks in block 2 were surveyed during the 1997/98 season. All paddocks in that block had thus been subjected to two full grazing seasons and were in the third grazing season. Grasses were identified by species, but non-grasses and sedges were not differentiated. The species were grouped into the three classes, namely palatable, intermediate and unpalatable (Table 5.1).

7.1.1 Initial species composition

Examination of Tables 7.1 to 7.4 show that the species composition between treatments within blocks was reasonably similar at the beginning of the trial. The exceptions were, of course, treatments E 7 and 16 in block one during the first grazing cycle (presented in italics in Table 7.1). The proportionate amount of *Rendlia altera* was high (17.9 and 16.6 % respectively). The subsequent changing of the paddock layout resulted in a more similar species composition. It was impossible, in a non-replicated trial of this sort to expect to have the same species composition throughout all paddocks.

7.1.2 Changes in species composition

As mentioned previously, cattle had grazed the veld on the trial site during winter on an *ad hoc* basis for several years before the initiation of this trial. The veld was burnt biennially during spring during that period and very little or no summer grazing took place. The grazing treatments applied during this trial were thus a radical departure from immediate previous practice. Grazing time changed from winter to summer, class of livestock changed from cattle to sheep and grazing pressure ranged from light to heavy. Changes in species composition could thus be expected in the long term. Note block one was only grazed three times and block two twice during the period under consideration. This was a relatively short period for measuring changes in species composition.

Although the species have been grouped into palatability classes, it is important to examine individual species as well as the species groups. The groups broadly represent grazing value for livestock production.

Euclidean distances (Greig-Smith 1983) were calculated as an objective means of evaluating overall patterns of change in species composition from the initial survey to the final survey between treatments (Figures 7.1 & 7.2). Initial and final species composition of each treatment are tabled in Tables 7.1 to 7.8. Examination of change patterns in each treatment (keeping blocks separate) does not immediately reveal any obvious treatment effects (Figure 7.1). In Block 1, the late time of stocking treatments appear to have had a greater species composition change than the early time of stocking treatments. This trend does not appear in Block 2. The E7 and L7 treatments in Block 2 are interesting in that E7 showed the greatest change in species composition, while the species composition in L7 showed the least change. Examination of Tables 7.3 and 7.4 reveal that the important changes in treatment E7 were declines in *Brachiaria serrata*, *Diheteropogon amplectens*, *Monocymbium ceresiiforme* (although the initial proportion was low) and *Setaria nigrirostris*. All are palatable species. Similar trends were observed in treatment L7, although the order of magnitude was not as great.

Calculation of the mean species composition for each treatment was done by grouping the data for the two blocks (Table 7.5 and 7.6). The patterns of change were again not obviously related to treatment, although it appeared that the species composition on the late time of stocking treatment changed more than on the early (Figure 7.1)

The species composition of each stocking rate treatment was calculated (mean of time of stocking treatments) (Table 7.7). The two intermediate stocking rates (10 and 13 sheep ha^{-1}) showed greater change in species composition than the two extremes (7 and 16 sheep ha^{-1}) (Figure 7.2). The effect could have been linear with increasing change from light to heavy stocking rates if not for the heavy stocking rate (16 sheep ha^{-1}). The main change appeared in the palatable species group in the two intermediate stocking rate treatments, while in the extreme treatments the palatable group remained relatively stable. A possible explanation could be that with increasing stocking rate from low to intermediate stocking rate treatments the species composition of the palatable grasses is negatively impacted. As stocking rate increases further to 16 sheep ha^{-1}, a wider range of species is grazed (Chapter 5), thus possibly spreading the negative impact of grazing over a wider range of species with subsequent lower overall impact.

The species composition on the late time of stocking treatments showed greater change than on the early treatments (Figure 7.2). These changes included greater declines in proportion of *Brachiaria serrata*, *Diheteropogon amplectens* and *Eragrostis racemosa*, coupled with greater increases in proportion of *Themeda triandra* and *Eulalia villosa* in the late time of stocking treatments. The decline in the palatable species could be attributed to greater selective grazing in the late time of stocking treatments (Chapter 5) with resultant greater negative impact on the palatable species.

Examination of the changes in proportion of certain individual species is useful in gaining further understanding of the impact of grazing.

7.1.2.1 Palatable species

The palatable species increased in proportion on block 1 on the early 7 and 10 treatments, and declined on the early 13 and 16 treatments. The late treatments all showed an increase in palatable species on block 1, except the late 10 treatment which showed a decline. On block 2, the palatable species remained approximately the same on the early 7 treatment, and declined on the rest of the early treatments. The late 16 treatment showed an increase in palatable species, while the rest of the late treatments showed a decline in proportion of palatable species.

Examination of individual species within the palatable class revealed some interesting trends. The three species that were observed to be the most palatable on the trial site, *Brachiaria serrata*, *Diheteropogon amplectens* and *Monocymbium ceresiiforme* all showed a decline in proportional species composition across all treatments with two exceptions. *Brachiaria serrata* increased on the early 7 treatment on block 1, while *Monocymbium ceresiiforme* increased on the late 7 treatment on block 1. Although intensive grazing pattern measurements were only carried out during the first three grazing seasons it seems safe to assume that the grazing patterns would have been similar for the remainder of the grazing seasons under consideration. Examination of Tables 5.9 to 5.32 reveal that the three species under consideration were grazed heavily and declined in proportionate mass during each season. This corresponded with subjective observations made on the grazing preferences of the sheep on the trial. It appears that these three species are not able to withstand heavy grazing. It is not possible to speculate whether the three species would disappear altogether from the veld if these treatments were maintained or not. Experience has shown that the initial proportions of all three species were relatively high for the area, and that most veld that is regularly grazed in summer in this area has much lower levels of all three species. This has been verified by examination of species composition data in the vicinity of Athole collected by Barnes (1990) as part of a wider survey.

Eulalia villosa is an interesting species that is abundant in this veld type (Acocks 1988). In spite of evidence of high tannin levels and a reputation of being unpalatable, *Eulalia villosa* was heavily grazed throughout the season in all but the lightest stocking rate treatments (Tables 5.9 to 5.32). In spite of this, there was a general increase in proportion of *Eulalia villosa* in most of the treatments.

Setaria nigrirostris was not distributed very uniformly across the trial site, and was consequently only present in a few treatments. Also, it is a loosely tufted grass with underground stems, which may be underrepresented in a nearest plant point survey, particularly in relation to its productivity. In all treatments where it was present it was grazed heavily, as evidenced by the decline in availability of herbage over the season. The only exception was the early 7 treatment on block 2, where it increased in mass until near the end of the season. In all treatments, *Setaria nigrirostris* declined in proportional species composition. Again, it appears to be a grass that does not withstand heavy grazing.

Themeda triandra is possibly the best known and most studied veld grass in South Africa. Subjective observation of the grazing patterns of the sheep revealed that on the high grazing pressure treatments (early stocking and high stocking rates), it was grazed heavily and consistently throughout the season. In the lower grazing pressure treatments, *Themeda triandra* was grazed very selectively. Tufts that were selected early in the season were kept short throughout the season, while tufts that were avoided early in the season were not grazed at all during the rest of the season. This pattern ties in with the measurements made on the availability of *Themeda triandra* herbage over the season (Tables 5.9 to 5.32). During the first season (block 1) it was generally heavily grazed on all treatments. During the next two seasons when total veld production was substantially higher, *Themeda triandra* was still well grazed, but availability of herbage mass tended to increase during the seasons on the lower grazing pressure treatments. In terms of proportional species composition, *Themeda triandra* increased on all treatments with the exception of the late 10 treatment on block 2. There was no logical explanation for this exception. It seems that the treatments generally favoured an increase in proportion of *Themeda triandra*.

Tristachya leucothrix was generally heavily grazed in all treatments (Tables 5.9 to 5.32). Its response to grazing was variable, with some increases and decreases seemingly unrelated to treatments (Tables 7.1 to 7.4).

The other species in the palatable group were either less well distributed across the treatments, occurred in low proportions, or were too inconsistent in response to treatment to warrant detailed discussion.

7.1.2.2 Intermediate species

The intermediate group of species was dominated by *Alloteropsis semialata* and tended to mirror the response of that species.

Alloteropsis semialata was one of the more dominant grass species in the area. It was placed in the intermediate category due to the sheep tending to avoid grazing it until the availability of other species declined, usually late in the season. Subjectively, it appeared that sheep performance dropped sharply at the time that sheep started to graze *Alloteropsis semialata*. The patterns of availability of this species during the season were closely coupled to grazing pressure (Tables 5.9 to 5.32). In terms of proportional species composition, the response of this species to the applied treatments was variable, with an apparent decline at high grazing pressure and a general increase in proportion at lower grazing pressure treatments.

Eragrostis curvula is the other species in the intermediate group worthy of discussion. This species is common in the area, particularly in heavily grazed and / or trampled localities. It was grazed readily in the beginning of the season, particularly on the early treatments. Once grazed, it was readily kept short for the rest of the season. In seasons when herbage availability was not limiting early in the season, it tended to increase in amount over the season. *Eragrostis curvula* showed an inconsistent response to treatments in terms of changes in proportional species composition.

The other species in the intermediate group contributed relatively little to the species composition as well as the amount of herbage available.

7.1.2.3 Unpalatable species

Apart from slight increases in the proportion of unpalatable species in the early 7, 13 and 16 treatments in block 1, the proportion of unpalatable species declined over the duration of the trial.

Loudetia simplex was only grazed if sheep were under extreme pressure. It declined consistently in species composition in all treatments. This was a particularly interesting response. Most of the patterns of change noted in the other species could be logically explained in terms of response to grazing. The fact that the proportion of *Loudetia simplex* changed even though it was almost never grazed suggests that other factors, possibly a change in competition level from other species or some other unknown factors, can cause a change in proportional composition.

Rendlia altera was the most important species in the unpalatable group. It was almost never grazed in this trial. It tends to occur in patches, and dominates in those patches, with little else growing in close association. It had a variable response to the applied treatments, showing a slight decline in proportional composition some treatments and a slight increase in other treatments.

7.1.2.4 Other species

Occasionally certain species were encountered that were unidentifiable. These were usually less than one percent of the total and were thus ignored in the interpretation of the data.

7.1.2.5 Non-grasses

A variety of non-grasses occur in this veld type (Acocks 1988) and several types of non-grasses were encountered on the trial site. The non-grasses on the site included *Berkheya setifera*, *B. zeyheri*, *Hypoxis obtusa*, *H. rigidula*, *H. argentea* and *Indigofera oxytropis*. The non-grasses increased in proportion in some treatments and decreased in others. The pattern of change did not appear to be a reflection of treatment.

7.2 Effect of treatments on veld vigour

While the measurement of changes in species composition is generally accepted as the standard means of determining treatment effects on veld condition, it is a long-term measure. Species composition is slow to change, and changes may be due to variations in environmental conditions or other unmeasured factors. It was felt that the measurement of the impact of the grazing treatment on vigour in the season following treatment, and compared to an ungrazed control, would provide a short-term measure of the impact of grazing on veld grass species.

The residual effects of the treatments were measured during the following season as described in Chapter 2. Data was pooled for the four quadrats in each exclosure plot. The mean of the fifty plots per paddock (either treated or control) was then taken as a single measure for each paddock. Comparisons were then made between the vigour of the treated plots and the control plots. Measurements were carried out during December of the season following a season of grazing. The residual effects were measured after each of three grazing seasons.

7.2.1 Residual effects of treatments on vigour measured during the December following the season in which the treatments were applied

The variations in species productivity between treatments mentioned previously made comparisons of the impact of the treatments on individual grass species difficult. Grouping of the species into palatability classes facilitated statistical comparisons. Both the palatable and intermediate classes were well represented in all treatments. The unpalatable class was however, less well distributed between treatments and was thus omitted from the comparisons, although the data is presented. The impact of the treatments on total veld production was also investigated.

7.2.1.1 Residual effects of the treatments on the palatable species

The impact of the treatments on the vigour of all species was calculated by measuring yield (kg DM ha^{-1}) of all species in veld grazed during the previous season, and in the comparable ungrazed control (Table 7.9 - 7.14). Examination of the impact of the grazing treatments in the previous season compared to the ungrazed control revealed that grazing had a severe negative impact on the vigour of the palatable species.

It is important to remember that this impact was measured in the season following treatment, i.e. the effect of the treatment lasted longer than the season in which the treatment was applied.

Almost without exception, the yield of the palatable species was lower in the previously grazed plots than in the ungrazed control. Consequently the yield of the group as a whole was also substantially lower in the previously grazed plots. The significance of the differences between the yield of the control and the previously grazed plots was investigated using analysis of regression. Each time of stocking treatment was investigated separately for each of the first three seasons. Parallel lines were fitted to the yield of the control plots, and to the yield of the grazed plots. A test was carried out to evaluate the significance of the difference in the Y intercept. In addition, the lines were tested for homogeneity of slope, which would indicate an interaction between stocking rate and the effect of grazing on the productivity of the grass species under consideration.

The grazing treatments significantly lowered the yield of the palatable group of species during all three seasons under consideration, as well as for both times of stocking. Parallel lines adequately described the yields of the control and grazed plots. The parallel lines are presented in Figure 7.3. All the lines fitted were significant ($P<0.01$). The differences between lines (i.e. the difference between the Y intercepts) were also all significant ($P<0.001$).

The fitted lines were tested for differences in slope, which would be an indication of a stocking rate effect on the yield depression caused by the grazing treatments. The slopes of all pairs of lines were found to be statistically similar ($P>0.05$), indicating that stocking rate did not have a significant effect on the yield depression of the palatable grasses in the previously grazed plots.

The evaluation of the effects of early and late stocking was best carried out by comparing the relative yields of the previously grazed plots expressed as a percentage of the yield of the control plots (Table 7.15 – 7.17). Parallel lines were fitted to the relative yields of the previously grazed plots for both the early and late treatments in each season.

No significant differences were found between the Y intercepts of the parallel lines fitted to the data from all three seasons. Also, no differences in slopes were found between the pairs of lines fitted (early versus late). It appears that the time of stocking had no significant impact on the yield depression of the palatable grasses in the previously grazed plots. There was also no significant interaction between time of stocking and stocking rate in terms of the relative productivity of the previously grazed plots.

Although the substantial variations in veld production between seasons hindered using the seasons as replications in an analysis of variance, the mean relative effects of the treatments over the three seasons contribute to the interpretation of the data. The relative mean yields of the palatable species in the previously grazed plots (Table 7.18) were 50.3 % of the yields in the control plots. The effects of stocking rate and time of stocking were apparently related to grazing pressure. The higher grazing pressure treatments had a lower yield than those with lower grazing pressure.

7.2.1.2 Residual effects of the treatments on the intermediate species

The intermediate group of species comprised a relatively small proportion of the available herbage during the grazing seasons, and most of the species within the group were not grazed as uniformly as species within the palatable group (Tables 7.9 – 7.14). The impact of the grazing treatments was thus variable across treatments and seasons. No significant differences were found between the parallel lines fitted to the yields of the previously grazed and the control plots. No significant departure from homogeneity of slope was detected. This implies that the impact of grazing, as well as the impact of the stocking rate treatments on the intermediate group of species were not significant.

Examination of the effects of the time of stocking on the relative yield of the previously grazed plots (Table 7.19) was carried out using regression analysis. No significant differences were found between the effects of early and late stocking.

Examination of the means of the relative yield of the intermediate species over the three seasons revealed that the mean yield of the previously grazed plots was 107.6 % (Table 7.19). There was a relation between yields and grazing pressure, with higher grazing pressure resulting in lower yields. There was a distinct decline in vigour of the intermediate group with increase in stocking rate and in the early time of stocking treatment in relation to the late treatments.

The intermediate group is particularly important in that it contains species that are generally only grazed consistently once the amount of the palatable species available drops below the level where intake of palatable species is sufficient for livestock requirements. The levels of utilisation of intermediate species appear to be more strongly related to climatic conditions than the utilisation of palatable species. It seems that during seasons of greater veld production, the utilisation of intermediate species declines relative to seasons in which veld productivity is relatively less. In contrast, the utilisation of the palatable species appears relatively constant between seasons.

7.2.1.3 Residual effects of the treatments on the unpalatable species

The unpalatable group of species generally made up a small percentage of the herbage available during the grazing season. The impact of the grazing treatments was thus more difficult to quantify accurately. Similar statistical tests were carried out on the yields of the unpalatable group as on the previous groups. No consistent significant differences were found between the yields of the control plots and the previously grazed plots (Tables 7.9 – 7.14). No significant departures from homogeneity of slope were found. This implies that the grazing treatments did not have a consistent effect on the unpalatable group of species. The effects of the early and late times of stocking on the relative yields of the previously grazed plots were not significant for each season (Tables 7.15 – 7.17).

The effects of the treatments on the relative yields of the unpalatable species in the previously grazed plots were more variable than for the palatable and intermediate palatability group (Table 7.20). It was still clear, however, that the yield of the unpalatable species had increased dramatically due to the applied treatments. There was a tendency for the yield of the unpalatable species to increase in response to grazing pressure. A consistent increase in relative yield of unpalatable species in response to stocking rate was observed (Table 7.20).

7.2.1.4 Residual effects of the treatments on all species grouped together

Examination of the impact of the grazing treatments on all species grouped together in the previous season compared to the ungrazed control (Table 7.9 – 7.14) revealed that grazing had a severe and consistent negative impact on the vigour of the total group of species. Parallel lines were fitted to the yields of the control plots as well as the previously grazed plots (Figure 7.4). The differences between the Y intercepts of the two lines were significant ($P<0.01$) in all cases. This demonstrates the severe negative impact that grazing had on the vigour of the veld.

The effect of stocking rate was again not significant in any of the seasons. This was shown by no significant deviations from homogeneity of slope in any of the seasons under consideration. The time of stocking did not make a significant difference to the depression in yield caused by grazing.

The relative mean yield of the total group of species declined to 65.2 % over the three seasons under consideration (Table 7.21). Increase in grazing pressure resulted in a decline in total yield for the three seasons grouped together. This was observed both in terms of stocking rate and time of stocking.

7.3 Discussion

The two methods used for evaluating the impact of grazing on veld provided useful insight into the response of the individual grass species to the applied treatments. The determination of proportional species composition has long been the standard means of quantifying grazing impact. The time period between the initial and final proportional species composition surveys in the current trial were probably too short for making accurate predictions on the impact of grazing on species composition. This is particularly relevant if one bears in mind the change in grazing management practice on the site with the implementation of the trial, and the fact that each paddock was grazed in alternate years. In spite of these potential shortcomings, certain trends emerged. The proportional composition of the three most palatable grasses, namely *Brachiaria serrata, Diheteropogon amplectens* and *Monocymbium ceresiiforme* declined. The proportion of *Themeda triandra*, although also well utilised, generally increased slightly.

The determination of the residual effect of grazing on the vigour of the grass relative to an ungrazed control provided a useful short-term measure of grazing impact where the impact of a treatment on vigour could be measured during the following season. The impact of the grazing treatments on most of the more abundant species was clear. The negative effect of grazing on the vigour of the three most palatable species, *Brachiaria serrata*, *Diheteropogon amplectens* and *Monocymbium ceresiiforme* was dramatic. This relates well to the decline in proportional species composition observed for these three species over the corresponding period. Vigour of *Themeda triandra* was negatively impacted in certain treatments and positively impacted in others. There appeared to be a negative relation between vigour and stocking rate for this species. Again, there is some agreement between the impact of treatment on vigour and the proportional species composition.

Table 7.1 Proportional species composition (%) of early time of stocking treatments measured during 1992/93 season and the 1996/97 season for block 1. Note that the new paddocks for treatments E7 and E16 were surveyed initially in 1994/95. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1995	1997	1993	1997	1993	1997	*1993*	1995	1997
	E 7	E 7	E 7	E 10	E 10	E 13	E 13	*E 16*	E 16	E 16
Palatable species										
Andapp	*0.0*	0.0	0.0	0.3	0.0	0.0	0.0	*0.0*	0.3	0.0
Brabri	*0.0*	0.0	0.3	0.3	0.0	0.0	0.7	*0.0*	0.0	0.7
Braser	*6.5*	1.0	4.0	8.0	1.7	6.3	3.3	*6.8*	8.6	1.7
Ctecon	*5.9*	0.3	0.3	1.3	0.0	1.7	0.0	*1.9*	0.3	0.0
Cynspp	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.0	0.0
Digfla	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.2	0.1
Digtri	*0.0*	0.0	2.0	0.7	0.0	0.0	1.3	*0.6*	0.6	0.0
Dihamp	*7.5*	8.3	0.0	7.0	0.0	2.3	0.0	*6.5*	1.9	0.0
Eracap	*1.3*	1.7	0.3	1.7	0.0	1.7	0.3	*2.6*	1.3	0.0
Eulvil	*3.6*	5.3	10.0	4.3	8.1	1.3	1.0	*2.3*	6.4	11.2
Hetcon	*0.7*	1.3	3.0	1.3	1.3	1.0	2.0	*1.3*	0.6	4.7
Hyphir	*0.3*	2.7	0.3	6.3	21.5	1.0	0.0	*3.2*	1.6	7.5
Moncer	*3.9*	4.3	3.0	4.7	1.7	3.3	0.3	*5.8*	1.6	1.0
Setnig	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	14.3	1.7
Setsph	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.0	0.7
Thetri	*6.2*	8.0	11.3	4.3	7.7	2.3	7.3	*3.9*	11.1	12.5
Trileu	*6.8*	9.0	9.6	10.6	13.8	22.6	17.8	*11.0*	6.7	8.8
Total	*42.7*	41.9	44.2	50.8	55.7	43.5	34.0	*46.1*	55.6	50.6
Intermediate species										
Allsem	*4.9*	6.6	7.6	15.6	13.1	18.3	19.5	*8.8*	16.6	15.9
Digmon	*0.0*	1.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.6	0.0
Eracur	*1.3*	2.0	6.0	1.7	4.7	1.3	3.0	*1.3*	1.9	5.8
Erapla	*0.0*	0.7	0.3	0.0	0.0	0.0	0.3	*0.6*	0.0	0.0
Erarac	*3.9*	6.3	6.0	5.3	3.0	3.0	1.7	*4.5*	0.6	0.7
Eraspp	*0.0*	0.0	0.3	0.0	0.0	0.0	0.0	*0.0*	0.3	0.0
Harfal	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.1	0.1
Melner	*0.0*	0.3	0.0	0.0	0.0	0.0	0.0	*0.0*	0.3	0.3
Miccaf	*1.0*	0.7	0.0	0.0	0.0	1.3	0.0	*1.0*	0.3	0.7
Paneck	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.0	0.0
Pannat	*3.6*	1.0	1.3	4.7	0.0	1.0	0.3	*5.8*	1.0	0.3
Sticon	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.3	0.0
Traspi	*7.2*	12.0	8.3	3.7	6.4	1.0	5.6	*3.2*	4.1	5.4
Sedges	*2.3*	1.7	1.3	1.7	2.0	2.0	4.0	*2.9*	2.2	0.0
Total	*24.1*	32.2	31.2	32.6	29.2	27.9	34.3	*28.2*	28.4	29.3
Unpalatable species										
Arispp	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.0	0.0
Cymexc	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	0.0	0.0
Lousim	*3.6*	2.0	0.7	4.3	0.0	2.0	0.0	*4.2*	1.3	0.7
Renalt	*17.9*	12.3	15.0	2.7	5.7	11.0	13.5	*16.6*	1.3	3.4
Total	*21.5*	14.3	15.6	7.0	5.7	13.0	13.5	*20.8*	2.5	4.1
Other	*0.0*	0.0	0.0	0.0	0.3	0.0	0.3	*0.0*	0.0	0.5
NG	*11.7*	11.6	9.0	9.6	9.1	15.6	17.8	*4.9*	13.4	15.6

Table 7.2 Proportional species composition (%) for late time of stocking treatments measured during 1992/93 season and the 1996/97 season for block 1. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997	1993	1997	1993	1997
	L 7	L 7	L 10	L 10	L 13	L 13	L 16	L 16
Palatable species								
Andapp	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brabri	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0
Braser	10.1	1.0	7.7	2.7	16.3	3.7	5.7	2.0
Ctecon	0.7	0.0	1.0	1.0	2.0	0.0	3.0	0.0
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digfla	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Digtri	0.0	0.0	0.0	2.7	0.3	3.7	0.0	0.0
Dihamp	7.2	1.0	6.0	0.0	7.2	0.0	6.7	0.0
Eracap	2.0	0.0	5.7	0.0	3.3	0.0	2.7	0.0
Eulvil	6.2	12.7	5.3	6.0	5.5	8.4	4.3	13.9
Hetcon	0.7	3.3	2.7	0.7	0.7	2.3	2.0	4.0
Hyphir	0.0	5.9	5.0	3.0	6.8	3.3	0.7	6.3
Moncer	2.0	7.5	4.3	0.7	2.6	1.7	4.7	3.3
Setnig	0.0	0.0	0.0	2.0	0.0	0.3	0.0	0.0
Setsph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thetri	18.6	32.2	14.0	16.1	9.4	30.4	8.3	20.2
Trileu	3.9	3.9	5.3	18.8	2.3	7.4	10.3	10.9
Total	51.6	67.4	57.0	53.7	56.7	62.0	48.3	60.6
Intermediate species								
Allsem	13.1	13.0	9.7	9.4	8.8	5.7	21.3	15.6
Digmon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eracur	1.6	2.0	0.3	10.7	2.3	6.4	0.7	1.7
Erapla	0.0	0.0	0.0	0.7	1.0	1.7	0.0	0.0
Erarac	9.8	1.0	8.0	0.3	4.6	2.0	8.0	2.6
Eraspp	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Harfal	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Melner	1.3	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Miccaf	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.3
Paneck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pannat	2.0	0.3	3.3	1.0	3.3	1.3	1.3	0.0
Sticon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traspi	2.0	2.3	4.0	6.0	4.2	8.7	1.3	0.7
Sedges	0.3	0.3	2.0	1.7	0.0	0.0	2.3	0.7
Total	30.1	18.9	28.3	29.9	24.1	26.6	35.3	21.5
Unpalatable species								
Arispp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lousim	5.2	1.6	3.7	0.3	4.6	1.3	2.7	0.0
Renalt	1.6	0.7	0.3	1.3	2.3	2.7	1.7	2.3
Total	6.9	2.3	4.0	1.7	6.8	4.0	4.3	2.3
Other	0.3	0.0	0.3	0.0	0.7	0.7	0.0	0.3
NG	11.1	11.4	10.3	14.8	11.7	6.7	12.0	15.2

Table 7.3 Proportional species composition (%) for early time of stocking treatments measured during the 1992/93 season and the 1996/97 season for block 2. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997	1993	1997	1993	1997
	E 7	E 7	E 10	E 10	E 13	E 13	E 16	E 16
Palatable species								
Andapp	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Brabri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Braser	10.6	3.7	9.9	2.7	11.7	3.3	16.2	4.6
Ctecon	0.0	0.0	0.3	0.0	0.7	0.0	1.0	0.0
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digfla	0.0	0.0	0.6	0.4	0.0	0.0	0.0	0.0
Digtri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dihamp	5.5	0.0	3.9	0.3	7.7	0.0	1.6	0.0
Eracap	0.6	0.0	0.3	0.3	0.7	0.3	0.6	0.3
Eulvil	8.7	15.7	2.6	1.7	6.7	5.0	4.5	5.6
Hetcon	1.0	0.3	3.6	0.0	2.3	1.7	3.2	2.3
Hyphir	1.6	2.7	9.9	9.4	0.7	1.7	2.3	2.3
Moncer	3.2	0.7	3.0	1.7	4.0	1.3	0.6	2.3
Setnig	11.3	0.0	0.3	0.0	3.0	0.0	0.0	0.0
Setsph	0.0	15.7	0.0	0.0	0.0	1.3	0.0	0.3
Thetri	11.9	13.7	15.5	17.4	16.3	23.0	11.0	11.4
Trileu	6.1	6.7	6.9	10.4	6.3	9.3	17.2	11.1
Total	60.6	59.0	57.5	44.4	60.0	47.0	58.4	40.2
Intermediate species								
Allsem	13.5	15.7	11.8	17.8	19.0	24.7	20.5	25.8
Digmon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eracur	1.6	0.7	3.3	11.1	0.3	1.0	1.0	2.0
Erapla	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Erarac	1.9	0.3	2.3	1.3	2.0	3.3	1.0	0.0
Eraspp	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Harfal	0.0	0.0	0.4	0.6	0.0	0.0	0.0	0.0
Melner	0.6	1.3	0.3	0.3	0.0	0.3	0.0	0.3
Miccaf	1.3	0.0	0.7	0.3	0.7	0.3	0.0	0.0
Paneck	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Pannat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sticon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Traspi	5.8	1.3	2.0	1.0	3.7	4.3	1.6	9.2
Sedges	0.3	0.7	1.3	0.0	0.7	0.0	1.3	0.0
Total	25.2	20.3	22.1	34.2	26.3	34.0	25.3	37.3
Unpalatable species								
Arispp	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lousim	3.9	0.0	2.3	0.0	3.0	0.7	3.2	0.0
Renalt	0.3	0.0	0.3	1.7	1.0	0.7	0.0	0.0
Total	4.2	0.0	2.6	2.0	4.0	1.3	3.2	0.0
Other	0.0	0.0	1.3	1.7	0.0	0.3	0.0	0.0
NG	10.0	20.7	16.4	17.8	9.7	17.3	13.0	22.5

Table 7.4 Proportional species composition (%) for late time of stocking treatments measured during the1992/93 season and the 1996/97 season for block 2. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997	1993	1997	1993	1997
	L 7	L 7	L 10	L 10	L 13	L 13	L 16	L 16
Palatable species								
Andapp	0.3	0.0	0.6	0.0	0.0	0.0	0.0	0.0
Brabri	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Braser	7.2	5.4	13.1	2.7	11.4	3.3	8.7	1.2
Ctecon	2.6	0.3	0.0	0.0	0.3	0.0	0.3	0.0
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digfla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digtri	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Dihamp	2.9	2.7	5.3	0.0	9.1	2.0	6.4	2.4
Eracap	0.0	0.3	0.3	0.3	0.7	0.0	0.3	0.0
Eulvil	6.9	10.8	4.4	12.3	7.7	11.2	6.7	14.9
Hetcon	3.3	0.3	0.9	0.7	0.7	0.7	3.0	2.4
Hyphir	0.3	0.3	4.4	5.5	0.7	2.6	0.3	0.3
Moncer	5.2	3.1	0.9	0.0	2.4	1.3	1.0	0.6
Setnig	1.6	0.0	3.7	0.0	6.4	0.0	2.3	0.0
Setsph	0.0	1.0	0.0	1.4	0.0	4.0	0.0	2.1
Thetri	11.1	11.5	15.6	8.2	11.1	13.2	17.4	25.3
Trileu	20.9	20.3	5.6	4.4	3.7	1.7	11.0	15.5
Total	63.1	56.3	55.1	35.5	54.2	39.9	57.5	64.9
Intermediate species								
Allsem	8.5	7.8	22.1	24.6	18.2	23.8	15.4	13.4
Digmon	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eracur	2.0	2.4	0.9	1.7	3.0	2.3	1.3	0.3
Erapla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Erarac	2.0	0.0	1.9	0.3	4.4	3.0	1.0	0.3
Eraspp	0.0	0.0	0.0	0.0	0.7	0.7	0.0	0.0
Harfal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melner	0.0	1.4	0.0	5.8	0.0	5.3	0.0	0.3
Miccaf	0.7	0.7	0.0	0.0	1.0	1.7	1.3	1.5
Paneck	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Pannat	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Sticon	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Traspi	2.6	3.1	1.6	5.1	4.4	1.3	6.0	1.5
Sedges	0.7	1.0	0.0	0.0	0.3	0.0	1.7	0.0
Total	16.7	16.3	26.8	37.5	32.3	38.0	27.1	17.4
Unpalatable species								
Arispp	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lousim	5.2	3.7	3.4	0.7	1.0	0.3	3.0	0.6
Renalt	1.6	0.7	0.0	0.0	0.3	0.0	1.0	0.3
Total	6.9	4.4	3.4	0.7	1.3	0.7	4.0	0.9
Other	0.0	1.4	0.0	0.3	0.0	0.0	0.0	0.3
NG	13.4	21.7	14.6	25.9	12.1	21.5	11.4	16.5

Table 7.5 Proportional species composition (%) for the early treatments (mean of block 1 & 2) measured during the 1992/93 season and the 1996/97 season. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997	1993	1997	1993	1997
	E 7	E 7	E 10	E 10	E 13	E 13	E 16	E 16
Palatable species								
Andapp	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.2
Brabri	0.0	0.2	0.2	0.0	0.0	0.3	0.0	0.0
Braser	5.8	3.8	8.9	2.2	9.0	3.3	12.4	6.6
Ctecon	0.2	0.2	0.8	0.0	1.2	0.0	0.6	0.2
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digfla	0.0	0.0	0.3	0.2	0.0	0.0	0.1	0.1
Digtri	0.0	1.0	0.3	0.0	0.0	0.7	0.3	0.3
Dihamp	6.9	0.0	5.5	0.2	5.0	0.0	1.8	1.0
Eracap	1.2	0.2	1.0	0.2	1.2	0.3	1.0	0.8
Eulvil	7.0	12.8	3.5	4.9	4.0	3.0	5.5	6.0
Hetcon	1.1	1.7	2.5	0.7	1.7	1.8	1.9	1.5
Hyphir	2.1	1.5	8.1	15.4	0.8	0.8	1.9	1.9
Moncer	3.8	1.8	3.8	1.7	3.7	0.8	1.1	1.9
Setnig	5.6	0.0	0.2	0.0	1.5	0.0	7.2	7.2
Setsph	0.0	7.8	0.0	0.0	0.0	0.7	0.0	0.2
Thetri	10.0	12.5	9.9	12.6	9.3	15.1	11.1	11.3
Trileu	7.5	8.2	8.8	12.1	14.5	13.6	11.9	8.9
Total	51.3	51.6	54.2	50.0	51.8	40.5	57.0	47.9
Intermediate species								
Allsem	10.1	11.7	13.7	15.4	18.6	22.1	18.5	21.2
Digmon	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.3
Eracur	1.8	3.3	2.5	7.9	0.8	2.0	1.4	1.9
Erapla	0.3	0.2	0.0	0.7	0.0	0.2	0.0	0.0
Erarac	4.1	3.2	3.8	2.2	2.5	2.5	0.8	0.3
Eraspp	0.0	0.3	0.0	0.0	0.0	0.0	0.2	0.2
Harfal	0.0	0.0	0.2	0.3	0.0	0.0	0.1	0.1
Melner	0.5	0.7	0.2	0.2	0.0	0.2	0.2	0.3
Miccaf	1.0	0.0	0.3	0.2	1.0	0.2	0.2	0.2
Paneck	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Pannat	0.5	0.7	2.3	0.0	0.5	0.2	0.5	0.5
Sticon	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Traspi	8.9	4.8	2.8	3.7	2.3	5.0	2.9	6.6
Sedges	1.0	1.0	1.5	1.0	1.3	2.0	1.8	1.1
Total	28.7	25.8	27.3	31.7	27.1	34.2	26.9	32.8
Unpalatable species								
Arispp	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lousim	2.9	0.3	3.3	0.0	2.5	0.3	2.3	0.6
Renalt	6.3	7.5	1.5	3.7	6.0	7.1	0.6	0.6
Total	9.2	7.8	4.8	3.9	8.5	7.4	2.9	1.3
Other	0.0	0.0	0.7	1.0	0.0	0.3	0.0	0.0
NG	10.8	14.8	13.0	13.4	12.6	17.6	13.2	18.0

Table 7.6 Proportional species composition (%) for the late treatments (mean of block 1 & 2) measured during the 1992/93 season and the 1996/97 season. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997	1993	1997	1993	1997
	L 7	L 7	L 10	L 10	L 13	L 13	L 16	L 16
Palatable species								
Andapp	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Brabri	0.2	0.0	0.0	0.0	0.2	0.2	0.0	0.0
Braser	8.7	3.2	10.4	2.7	13.9	3.5	7.2	1.6
Ctecon	1.6	0.2	0.5	0.5	1.1	0.0	1.7	0.0
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digfla	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Digtri	0.2	0.0	0.2	1.3	0.2	1.8	0.0	0.0
Dihamp	5.1	1.8	5.6	0.0	8.1	1.0	6.5	1.2
Eracap	1.0	0.2	3.0	0.2	2.0	0.0	1.5	0.0
Eulvil	6.5	11.8	4.8	9.2	6.6	9.8	5.5	14.4
Hetcon	2.0	1.8	1.8	0.7	0.7	1.5	2.5	3.2
Hyphir	0.2	3.1	4.7	4.2	3.8	3.0	0.5	3.3
Moncer	3.6	5.3	2.6	0.3	2.5	1.5	2.8	2.0
Setnig	0.8	0.0	1.9	1.0	3.2	0.2	1.2	0.0
Setsph	0.0	0.5	0.0	0.7	0.0	2.0	0.0	1.1
Thetri	14.9	21.9	14.8	12.1	10.3	21.8	12.9	22.8
Trileu	12.4	12.1	5.5	11.6	3.0	4.5	10.7	13.2
Total	57.4	61.8	56.1	44.6	55.4	51.0	52.9	62.8
Intermediate species								
Allsem	10.8	10.4	15.9	17.0	13.5	14.7	18.4	14.5
Digmon	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eracur	1.8	2.2	0.6	6.2	2.7	4.3	1.0	1.0
Erapla	0.0	0.0	0.0	0.3	0.5	0.8	0.0	0.0
Erarac	5.9	0.5	4.9	0.3	4.5	2.5	4.5	1.5
Eraspp	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0
Harfal	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Melner	0.7	0.7	0.3	2.9	0.0	2.6	0.0	0.2
Miccaf	0.3	0.3	0.2	0.0	0.5	0.8	0.8	0.9
Paneck	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Pannat	1.0	0.2	1.8	0.5	1.6	0.7	0.7	0.0
Sticon	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Traspi	2.3	2.7	2.8	5.6	4.3	5.0	3.7	1.1
Sedges	0.5	0.7	1.0	0.8	0.2	0.0	2.0	0.3
Total	23.4	17.6	27.6	33.7	28.2	32.3	31.2	19.5
Unpalatable species								
Arispp	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lousim	5.2	2.7	3.5	0.5	2.8	0.8	2.8	0.3
Renalt	1.6	0.7	0.2	0.7	1.3	1.3	1.3	1.3
Total	6.9	3.3	3.7	1.2	4.1	2.3	4.2	1.6
Other	0.2	0.7	0.2	0.2	0.3	0.4	0.0	0.3
NG	12.3	16.5	12.5	20.4	11.9	14.1	11.7	15.8

Table 7.7 Proportional species composition (%) for the stocking rate treatments (mean of the early and late time of stocking treatments) measured during the 1992/93 season and the 1996/97 season. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997	1993	1997	1993	1997
	7	7	10	10	13	13	16	16
Palatable species								
Andapp	0.2	0.0	0.4	0.0	0.0	0.0	0.1	0.1
Brabri	0.1	0.1	0.1	0.0	0.1	0.2	0.0	0.0
Braser	7.2	3.5	9.6	2.4	11.4	3.4	9.8	4.1
Ctecon	0.9	0.2	0.7	0.3	1.2	0.0	1.2	0.1
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digfla	0.0	0.0	0.2	0.1	0.0	0.1	0.1	0.1
Digtri	0.1	0.5	0.2	0.7	0.1	1.2	0.2	0.2
Dihamp	6.0	0.9	5.6	0.1	6.6	0.5	4.1	1.1
Eracap	1.1	0.2	2.0	0.2	1.6	0.2	1.2	0.4
Eulvil	6.8	12.3	4.2	7.0	5.3	6.4	5.5	10.2
Hetcon	1.6	1.7	2.1	0.7	1.2	1.7	2.2	2.3
Hyphir	1.1	2.3	6.4	9.8	2.3	1.9	1.2	2.6
Moncer	3.7	3.5	3.2	1.0	3.1	1.2	2.0	2.0
Setnig	3.2	0.0	1.0	0.5	2.3	0.1	4.2	3.6
Setsph	0.0	4.2	0.0	0.3	0.0	1.3	0.0	0.6
Thetri	12.4	17.2	12.3	12.4	9.8	18.5	12.0	17.0
Trileu	10.0	10.1	7.1	11.8	8.7	9.0	11.3	11.1
Total	54.3	56.7	55.1	47.3	53.6	45.7	55.0	55.3
Intermediate species								
Allsem	10.4	11.0	14.8	16.2	16.1	18.4	18.4	17.8
Digmon	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Eracur	1.8	2.7	1.6	7.1	1.7	3.2	1.2	1.5
Erapla	0.2	0.1	0.0	0.5	0.2	0.5	0.0	0.0
Erarac	5.0	1.8	4.4	1.3	3.5	2.5	2.7	0.9
Eraspp	0.0	0.2	0.0	0.0	0.2	0.2	0.1	0.1
Harfal	0.0	0.0	0.1	0.2	0.0	0.1	0.0	0.0
Melner	0.6	0.7	0.2	1.5	0.0	1.4	0.1	0.2
Miccaf	0.7	0.2	0.2	0.1	0.8	0.5	0.5	0.5
Paneck	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0
Pannat	0.7	0.4	2.1	0.3	1.1	0.4	0.6	0.2
Sticon	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1
Traspi	5.6	3.7	2.8	4.6	3.3	5.0	3.3	3.9
Sedges	0.7	0.8	1.2	0.9	0.7	1.0	1.9	0.7
Total	26.0	21.7	27.4	32.7	27.7	33.2	29.0	26.2
Unpalatable species								
Arispp	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lousim	4.1	1.5	3.4	0.3	2.6	0.6	2.5	0.5
Renalt	4.0	4.1	0.8	2.2	3.6	4.2	1.0	1.0
Total	8.1	5.6	4.3	2.5	6.3	4.9	3.5	1.4
Other	0.1	0.3	0.4	0.6	0.2	0.3	0.0	0.2
NG	11.5	15.7	12.8	16.9	12.3	15.8	12.4	16.9

Table 7.8 Proportional species composition (%) for the early and late time of stocking treatments (mean of the stocking rate treatments) measured during 1992/93 season and the 1996/97 season. A full list of species names and abbreviations is tabled in Appendix 2

	1993	1997	1993	1997
	E	E	L	L
Palatable species				
Andapp	0.2	0.0	0.2	0.0
Brabri	0.0	0.1	0.1	0.0
Braser	9.0	4.0	10.0	2.8
Ctecon	0.7	0.1	1.2	0.2
Cynspp	0.0	0.0	0.0	0.0
Digfla	0.1	0.1	0.0	0.1
Digtri	0.2	0.5	0.1	0.8
Dihamp	4.8	0.3	6.3	1.0
Eracap	1.1	0.4	1.9	0.1
Eulvil	5.0	6.7	5.9	11.3
Hetcon	1.8	1.4	1.7	1.8
Hyphir	3.2	4.9	2.3	3.4
Moncer	3.1	1.6	2.9	2.3
Setnig	3.6	1.8	1.8	0.3
Setsph	0.0	2.2	0.0	1.1
Thetri	10.1	12.9	13.2	19.7
Trileu	10.7	10.7	7.9	10.4
Total	53.6	47.5	55.4	55.0
Intermediate species				
Allsem	15.2	17.6	14.6	14.2
Digmon	0.2	0.1	0.0	0.0
Eracur	1.6	3.8	1.5	3.4
Erapla	0.1	0.3	0.1	0.3
Erarac	2.8	2.0	4.9	1.2
Eraspp	0.0	0.1	0.1	0.1
Harfal	0.1	0.1	0.0	0.1
Melner	0.2	0.3	0.2	1.6
Miccaf	0.6	0.1	0.5	0.5
Paneck	0.0	0.0	0.0	0.0
Pannat	0.9	0.3	1.3	0.3
Sticon	0.0	0.0	0.0	0.0
Traspi	4.2	5.0	3.3	3.6
Sedges	1.4	1.3	0.9	0.5
Total	27.5	31.1	27.6	25.8
Unpalatable species				
Arispp	0.0	0.0	0.0	0.0
Cymexc	0.0	0.0	0.0	0.0
Lousim	2.7	0.3	3.6	1.1
Renalt	3.6	4.7	1.1	1.0
Total	6.4	5.1	4.7	2.1
Other	0.2	0.3	0.2	0.4
NG	12.4	15.9	12.1	16.7

Table 7.9 Yields of all grass species measured in the December following the season in which veld was grazed according to treatment (G) or rested as a control (R) for the 1992/93 season early treatments. A full list of species names and abbreviations is tabled in Appendix 2

1992/93	E7 R	E7 G	E10 R	E10 G	E13 R	E13 G	E16 R	E16 G
Palatable species								
Andapp	0	0	0	0	0	2	2	3
Brabri	0	0	34	0	0	0	0	0
Braser	165	27	192	78	465	152	241	87
Ctecon	90	14	56	9	81	23	75	12
Cynspp	0	0	0	0	0	0	0	0
Digfla	8	23	1	6	14	8	16	15
Digtri	0	0	0	0	0	0	0	0
Dihamp	405	131	438	292	272	192	515	273
Eracap	2	0	1	2	2	3	0	1
Eulvil	306	8	76	14	126	2	152	20
Hetcon	24	15	60	17	14	17	39	21
Hyphir	26	5	152	250	1	29	51	104
Moncer	39	16	18	40	4	10	28	6
Setnig	0	0	1	0	0	0	59	1
Setsph	0	0	10	0	0	0	0	0
Thetri	477	57	352	105	301	67	456	32
Trileu	75	46	39	79	168	169	60	94
Total	1618	343	1430	892	1449	674	1694	669
Intermediate species								
Allsem	195	20	417	455	507	186	213	118
Digmon	0	0	0	0	0	0	0	0
Eracur	2	15	20	35	6	13	8	19
Erapla	0	0	0	0	0	0	1	0
Erarac	13	18	23	87	7	20	8	62
Eraspp	6	0	3	2	2	2	9	6
Harfal	0	0	1	0	0	0	0	0
Melner	0	2	33	19	5	2	10	7
Miccaf	0	0	0	0	1	0	0	1
Paneck	2	0	1	0	1	0	2	15
Pannat	63	7	140	8	105	3	216	9
Sticon	0	0	0	0	0	0	0	0
Traspi	58	253	72	19	15	17	91	10
Sedges	6	5	2	17	6	5	3	0
Total	343	319	711	642	657	248	562	247
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0	0	0
Lousim	29	40	4	5	21	3	61	13
Renalt	218	656	37	2	96	300	166	482
Total	247	696	41	7	117	302	227	494
Other	0	0	9	27	0	0	0	0
Total	2208	1358	2191	1569	2223	1224	2482	1410

Table 7.10 Yields of all grass species measured in the December following the season in which veld was grazed according to treatment (G) or rested as a control (R) for the 1992/93 season late treatments. A full list of species names and abbreviations is tabled in Appendix 2

1992/93	L7 R	L7 G	L10 R	L10 G	L13 R	L13 G	L16 R	L16 G
Palatable species								
Andapp	0	0	15	5	0	0	0	0
Brabri	0	1	14	22	9	0	0	0
Braser	240	107	271	174	181	173	286	287
Ctecon	39	6	93	9	60	2	51	7
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	1	2	2	0	2	3	2
Digtri	0	0	0	0	0	0	0	0
Dihamp	381	77	367	126	666	293	268	210
Eracap	3	4	3	0	17	10	3	6
Eulvil	262	76	305	29	173	18	368	31
Hetcon	57	46	11	16	57	24	49	59
Hyphir	5	28	133	102	232	204	18	74
Moncer	66	11	12	2	42	22	36	41
Setnig	20	0	483	251	0	2	63	9
Setsph	0	0	152	48	10	0	0	0
Thetri	593	508	253	272	540	216	524	154
Trileu	38	14	103	273	12	33	30	53
Total	1705	879	2218	1331	2000	999	1701	931
Intermediate species								
Allsem	206	403	135	186	106	88	729	212
Digmon	0	0	0	0	0	0	0	0
Eracur	41	17	17	82	37	16	17	22
Erapla	0	0	1	7	0	0	0	1
Erarac	22	16	7	14	19	45	11	63
Eraspp	0	1	2	2	0	8	1	0
Harfal	0	0	2	1	0	0	0	0
Melner	42	22	4	7	9	5	55	42
Miccaf	6	0	0	0	0	0	3	0
Paneck	0	0	0	0	0	0	0	1
Pannat	38	86	47	62	73	32	25	1
Sticon	0	0	0	0	0	0	0	0
Traspi	46	145	36	153	43	66	41	28
Sedges	1	0	5	3	0	1	5	19
Total	401	691	256	518	287	261	887	389
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0	0	0
Lousim	10	32	38	64	47	39	2	10
Renalt	0	0	17	44	13	18	2	8
Total	10	32	55	107	60	57	4	18
Other	0	0	0	0	2	3	0	0
Total	2116	1602	2529	1956	2348	1320	2591	1339

Table 7.11 Yields of all grass species measured in the December following the season in which veld was grazed according to treatment (G) or rested as a control (R) for the 1993/94 season early treatments. A full list of species names and abbreviations is tabled in Appendix 2

1993/94	E7 R	E7 G	E10 R	E10 G	E13 R	E13 G	E16 R	E16 G
Palatable species								
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	1	0	0	0	0	0
Braser	144	8	211	11	178	42	300	93
Ctecon	2	8	95	1	0	0	56	2
Cynspp	0	0	0	0	0	0	0	0
Digfla	1	0	0	6	1	2	2	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	215	20	345	27	226	12	172	12
Eracap	0	1	0	0	0	1	0	0
Eulvil	293	151	125	6	219	17	103	31
Hetcon	7	4	34	18	11	3	60	3
Hyphir	0	1	77	7	0	0	62	5
Moncer	0	0	6	4	16	4	3	7
Setnig	295	143	21	10	158	43	158	6
Setsph	0	0	0	0	10	0	0	0
Thetri	364	462	488	239	612	434	594	53
Trileu	69	43	38	54	22	34	81	64
Total	1391	841	1441	383	1453	591	1592	276
Intermediate species								
Allsem	285	376	195	324	269	396	429	353
Digmon	0	0	0	0	0	0	0	0
Eracur	0	11	40	72	4	3	2	32
Erapla	0	0	0	0	0	0	0	0
Erarac	1	3	2	5	4	19	0	1
Eraspp	12	9	1	1	0	4	0	1
Harfal	0	0	0	0	0	0	0	0
Melner	1	2	1	0	17	5	13	0
Miccaf	1	7	0	9	0	1	0	0
Paneck	0	0	0	0	0	0	4	0
Pannat	0	0	2	0	0	0	0	0
Sticon	0	0	0	0	0	0	0	0
Traspi	159	146	104	114	32	19	49	20
Sedges	0	2	4	3	0	0	0	6
Total	460	555	348	528	327	447	496	413
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0	30	0
Lousim	20	6	13	25	2	1	8	12
Renalt	0	4	1	13	0	16	0	1
Total	20	9	14	38	2	17	37	13
Other	0	0	5	5	0	0	0	1
Total	1871	1405	1808	954	1781	1055	2125	703

Table 7.12 Yields of all grass species measured in the December following the season in which veld was grazed according to treatment (G) or rested as a control (R) for the 1993/94 season late treatments. A full list of species names and abbreviations is tabled in Appendix 2

1993/94	L7 R	L7 G	L10 R	L10 G	L13 R	L13 G	L16 R	L16 G
Palatable species								
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	1	0
Braser	281	63	225	138	225	45	148	50
Ctecon	18	12	1	3	0	0	27	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	5	0	3	0	0	2	0	1
Digtri	0	0	1	0	0	0	2	1
Dihamp	303	66	148	23	177	8	128	23
Eracap	0	0	0	1	0	0	0	0
Eulvil	173	25	280	35	183	6	229	16
Hetcon	27	30	2	31	20	12	12	17
Hyphir	0	0	36	53	0	1	1	2
Moncer	15	1	4	1	19	2	25	5
Setnig	17	4	273	37	88	30	163	41
Setsph	0	0	0	0	30	8	0	10
Thetri	397	605	292	300	388	352	444	426
Trileu	137	158	56	57	54	36	100	198
Total	1373	964	1321	680	1184	502	1278	791
Intermediate species								
Allsem	179	197	374	546	418	358	237	275
Digmon	0	0	0	0	0	0	0	0
Eracur	2	4	14	4	14	26	13	4
Erapla	0	0	1	1	0	0	0	0
Erarac	3	5	2	2	2	8	1	2
Eraspp	1	3	0	0	0	1	0	0
Harfal	0	0	9	0	0	0	1	1
Melner	0	0	34	4	11	0	0	0
Miccaf	0	0	0	0	0	6	1	1
Paneck	0	0	0	0	0	0	0	1
Pannat	0	0	1	0	3	1	6	1
Sticon	0	0	0	0	0	0	0	0
Traspi	43	81	42	78	5	42	63	46
Sedges	1	1	0	0	2	0	1	0
Total	229	291	477	636	454	443	321	330
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	16	0	0	0	0	0	0	1
Lousim	27	49	8	44	3	16	1	15
Renalt	1	17	0	0	1	6	0	0
Total	44	67	8	44	4	22	1	16
Other	0	0	0	1	0	0	0	0
Total	1645	1321	1806	1361	1643	967	1600	1137

Table 7.13 Yields of all grass species measured in the December following the season in which veld was grazed according to treatment (G) or rested as a control (R) for the 1994/95 season early treatments. A full list of species names and abbreviations is tabled in Appendix 2

1994/95	E7 R	E7 G	E10 R	E10 G	E13 R	E13 G	E16 R	E16 G
Palatable species								
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	9	0	9	0	7	17
Braser	97	25	68	27	247	56	276	61
Ctecon	1	1	1	0	11	0	7	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	1	0	1	2	12	6	0	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	263	56	702	71	661	62	179	49
Eracap	2	1	1	0	0	0	0	0
Eulvil	84	227	102	133	66	9	178	98
Hetcon	30	53	28	84	72	27	44	52
Hyphir	89	24	135	27	54	14	5	15
Moncer	50	42	35	3	17	2	10	4
Setnig	0	0	11	0	0	0	262	127
Setsph	0	0	0	0	0	0	0	0
Thetri	486	448	150	126	325	56	371	197
Trileu	8	26	42	147	90	244	28	52
Total	1111	903	1284	620	1563	476	1367	673
Intermediate species								
Allsem	148	128	120	234	211	178	343	324
Digmon	0	0	0	0	0	0	0	0
Eracur	0	2	2	13	0	7	1	13
Erapla	0	0	0	7	2	0	0	0
Erarac	4	5	23	21	13	13	1	4
Eraspp	0	0	1	0	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	115	7	91	13	0	4	1	8
Miccaf	0	0	1	1	0	1	1	3
Paneck	0	0	0	0	0	0	0	0
Pannat	27	11	8	3	32	3	0	2
Sticon	0	0	0	0	0	0	0	0
Traspi	135	197	71	143	103	138	30	87
Sedges	0	3	2	1	0	0	0	0
Total	429	354	319	436	360	343	377	442
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	8	0	5	8	6	0	17	4
Lousim	38	52	11	22	15	6	32	58
Renalt	37	79	6	2	109	163	1	5
Total	84	131	23	32	129	169	50	68
Other	0	0	0	0	0	0	0	0
Total	1623	1389	1626	1087	2053	989	1794	1182

Table 7.14 Yields of all grass species measured in the December following the season in which veld was grazed according to treatment (G) or rested as a control (R) for the 1994/95 season late treatments. A full list of species names and abbreviations is tabled in Appendix 2

1994/95	L7 R	L7 G	L10 R	L10 G	L13 R	L13 G	L16 R	L16 G
Palatable species								
Andapp	0	0	0	0	0	0	0	0
Brabri	0	3	4	22	0	0	0	0
Braser	81	18	161	40	85	29	99	46
Ctecon	3	0	0	11	3	4	0	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	0	0	0	2	0	0
Digtri	0	9	0	0	0	0	0	0
Dihamp	538	221	258	66	602	179	561	153
Eracap	0	0	0	0	1	0	0	0
Eulvil	68	113	121	32	85	104	133	103
Hetcon	55	38	29	22	29	40	25	57
Hyphir	82	55	127	65	309	177	71	33
Moncer	31	3	0	0	58	79	43	14
Setnig	0	0	277	0	0	0	10	1
Setsph	0	0	1	0	0	0	0	0
Thetri	258	236	517	265	510	627	347	301
Trileu	44	94	149	168	14	31	14	48
Total	1160	792	1645	691	1695	1272	1305	754
Intermediate species								
Allsem	120	106	274	121	87	109	255	248
Digmon	0	0	0	0	0	0	0	0
Eracur	1	2	10	7	6	18	31	6
Erapla	0	1	0	5	5	0	0	0
Erarac	18	19	2	1	21	22	15	9
Eraspp	0	0	0	0	0	1	0	3
Harfal	0	0	7	0	0	0	0	0
Melner	19	15	0	0	34	2	30	37
Miccaf	0	0	0	2	0	0	0	0
Paneck	0	0	0	0	0	1	0	0
Pannat	8	5	48	57	28	6	6	0
Sticon	0	69	0	0	0	0	0	0
Traspi	141	166	269	457	96	123	117	96
Sedges	1	6	2	4	0	1	0	3
Total	308	387	611	654	276	282	454	402
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	5	2	19	14	0	0	0	0
Lousim	11	24	16	1	91	50	2	16
Renalt	49	26	24	27	5	13	0	5
Total	66	52	59	42	95	63	2	21
Other	0	0	0	0	0	0	0	0
Total	1534	1231	2315	1387	2067	1617	1760	1177

Table 7.15 Relative yields of grass species grazed according to treatment expressed as a percentage of the control treatment in the 1992/93 season. Measurements were done during the December of the following the season. A full list of species names and abbreviations is tabled in Appendix 2

1992/93	E7 G	E10 G	E13 G	E16 G	L7 G	L10 G	L13 G	L16 G
Palatable species								
Andapp	0	0	0	185	0	30	0	0
Brabri	0	0	0	0	0	154	0	0
Braser	16	41	33	36	45	64	96	100
Ctecon	16	15	29	16	15	10	3	13
Cynspp	0	0	0	0	0	0	0	0
Digfla	311	685	54	89	0	90	0	71
Digtri	0	0	0	0	0	0	0	0
Dihamp	32	67	71	53	20	34	44	78
Eracap	12	263	104	121	144	0	59	183
Eulvil	3	18	2	13	29	9	11	8
Hetcon	63	29	119	54	81	151	42	120
Hyphir	21	164	2268	203	518	77	88	404
Moncer	41	221	265	22	16	17	53	113
Setnig	0	0	0	2	0	52	0	14
Setsph	0	0	0	0	0	32	0	0
Thetri	12	30	22	7	86	107	40	29
Trileu	61	201	100	157	38	265	282	176
Total	21	62	47	39	52	60	50	55
Intermediate species								
Allsem	10	109	37	55	196	137	83	29
Digmon	0	0	0	0	0	0	0	0
Eracur	796	175	203	234	41	490	44	131
Erapla	0	0	0	0	0	941	0	0
Erarac	131	386	283	758	75	208	237	565
Eraspp	0	63	68	61	0	131	0	0
Harfal	0	0	0	0	0	43	0	0
Melner	0	57	28	71	52	177	48	76
Miccaf	0	0	14	0	0	0	0	0
Paneck	0	0	0	917	0	0	0	194
Pannat	12	5	3	4	229	131	44	6
Sticon	0	0	0	0	0	0	0	0
Traspi	439	26	113	10	316	423	156	69
Sedges	83	1040	83	0	22	61	0	407
Total	93	90	38	44	172	202	91	44
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0	0	0
Lousim	139	131	12	21	319	169	83	594
Renalt	301	6	312	290	0	259	137	419
Total	282	18	258	218	319	197	95	500
Other	0	296	0	0	0	0	119	0
Total	62	72	55	57	76	77	56	52

Table 7.16 Relative yields of grass species grazed according to treatment expressed as a percentage of the control treatment in the 1993/94 season. Measurements were done during the December of the following the season. A full list of species names and abbreviations is tabled in Appendix 2

1993/94	E7 G	E10 G	E13 G	E16 G	L7 G	L10 G	L13 G	L16 G
Palatable species								
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	0	0	0	0	0	0
Braser	5	5	24	31	22	61	20	34
Ctecon	463	1	0	3	69	356	0	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	0	222	23	0	0	0	221
Digtri	0	0	0	0	0	0	0	94
Dihamp	10	8	6	7	22	16	5	18
Eracap	0	0	0	0	0	381	0	0
Eulvil	51	5	8	30	14	13	3	7
Hetcon	49	54	31	5	111	1414	60	152
Hyphir	0	9	0	8	0	146	0	205
Moncer	0	65	24	236	5	38	9	21
Setnig	49	48	27	4	21	14	34	25
Setsph	0	0	0	0	0	0	27	0
Thetri	127	49	71	9	152	102	91	96
Trileu	62	143	153	79	115	101	65	199
Total	60	27	41	17	70	51	42	62
Intermediate species								
Allsem	132	166	147	82	110	146	86	116
Digmon	0	0	0	0	0	0	0	0
Eracur	0	181	80	2045	241	32	187	33
Erapla	0	0	0	0	0	132	0	0
Erarac	199	255	448	0	158	99	411	219
Eraspp	73	51	0	0	330	0	0	0
Harfal	0	0	0	0	0	0	0	241
Melner	241	0	31	0	0	11	0	0
Miccaf	1301	0	0	0	0	0	0	138
Paneck	0	0	0	0	0	0	0	0
Pannat	0	0	0	0	0	0	45	11
Sticon	0	0	0	0	0	0	0	0
Traspi	91	110	59	41	190	187	842	73
Sedges	420	81	0	0	61	0	0	0
Total	121	152	137	83	127	133	97	103
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	0	0	0	0	0	0	0
Lousim	29	201	91	159	182	592	561	1412
Renalt	0	1323	0	0	1388	0	527	0
Total	47	281	1104	34	151	592	551	1493
Other	0	111	0	0	0	0	0	0
Total	75	53	59	33	80	75	59	71

Table 7.17 Relative yields of grass species grazed according to treatment expressed as a percentage of the control treatment in the 1994/95 season. Measurements were done during the December of the following the season. A full list of species names and abbreviations is tabled in Appendix 2

1994/95	E7 G	E10 G	E13 G	E16 G	L7 G	L10 G	L13 G	L16 G
Palatable species								
Andapp	0	0	0	0	0	0	0	0
Brabri	0	0	5	232	0	505	0	0
Braser	26	39	23	22	23	25	34	46
Ctecon	46	43	2	0	0	2693	147	0
Cynspp	0	0	0	0	0	0	0	0
Digfla	0	137	54	0	0	0	0	0
Digtri	0	0	0	0	0	0	0	0
Dihamp	21	10	9	27	41	25	30	27
Eracap	49	35	0	0	163	0	33	0
Eulvil	269	131	13	55	167	27	122	77
Hetcon	177	303	38	119	70	76	141	225
Hyphir	27	20	25	325	67	51	57	46
Moncer	83	9	12	43	9	0	136	33
Setnig	0	0	0	48	0	0	0	6
Setsph	0	0	0	0	0	0	0	0
Thetri	92	84	17	53	91	51	123	87
Trileu	345	353	272	183	213	113	213	333
Total	81	48	30	49	68	42	75	58
Intermediate species								
Allsem	86	195	84	95	88	44	126	97
Digmon	0	0	0	0	0	0	0	0
Eracur	0	581	0	1078	242	75	294	19
Erapla	0	0	0	0	0	0	0	0
Erarac	135	93	100	335	107	23	108	60
Eraspp	0	0	0	0	0	0	0	0
Harfal	0	0	0	0	0	0	0	0
Melner	6	14	0	605	77	0	7	124
Miccaf	0	108	0	426	0	0	0	0
Paneck	0	0	0	0	0	0	0	0
Pannat	41	33	9	0	54	121	22	0
Sticon	0	0	0	0	0	0	0	0
Traspi	146	200	134	294	118	170	128	82
Sedges	0	54	0	0	886	231	0	751
Total	83	136	95	117	126	107	102	89
Unpalatable species								
Arispp	0	0	0	0	0	0	0	0
Cymexc	0	141	0	26	46	74	0	0
Lousim	137	197	44	184	213	3	55	994
Renalt	212	32	150	386	52	114	288	0
Total	157	139	131	137	80	71	66	1321
Other	0	0	0	0	0	0	0	0
Total	86	67	48	66	80	60	78	67

Table 7.18 Relative mean yields (%) of the palatable species in the previously grazed plots over the three seasons under consideration

Time of stocking	Stocking Rate				Mean
	7	10	13	16	
Early	54.0	45.7	39.3	35.0	43.5
Late	63.3	51.0	55.7	58.3	57.1
Mean	58.7	48.3	47.5	46.7	50.3

Table 7.19 Relative mean yields (%) of the intermediate species in the previously grazed plots over the three seasons under consideration

Time of stocking	Stocking Rate				Mean
	7	10	13	16	
Early	99.0	126.0	90.0	81.3	99.1
Late	141.7	147.3	96.7	78.7	116.1
Mean	120.3	136.7	93.3	80.0	107.6

Table 7.20 Relative mean yields (%) of the unpalatable species in the previously grazed plots over the three seasons under consideration

Time of stocking	Stocking Rate				Mean
	7	10	13	16	
Early	162.0	146.0	498.0	130.0	234.0
Late	183.0	287.0	237.0	1105.0	453.0
Mean	173.0	216.0	368.0	617.0	343.0

Table 7.21 Relative mean yields (%) of the total group of species in the previously grazed plots over the three seasons under consideration

Time of stocking	Stocking Rate				Mean
	7	10	13	16	
Early	74.3	64.0	54.0	52.0	61.1
Late	78.7	70.7	64.3	63.3	69.2
Mean	76.5	67.3	59.2	57.5	65.2

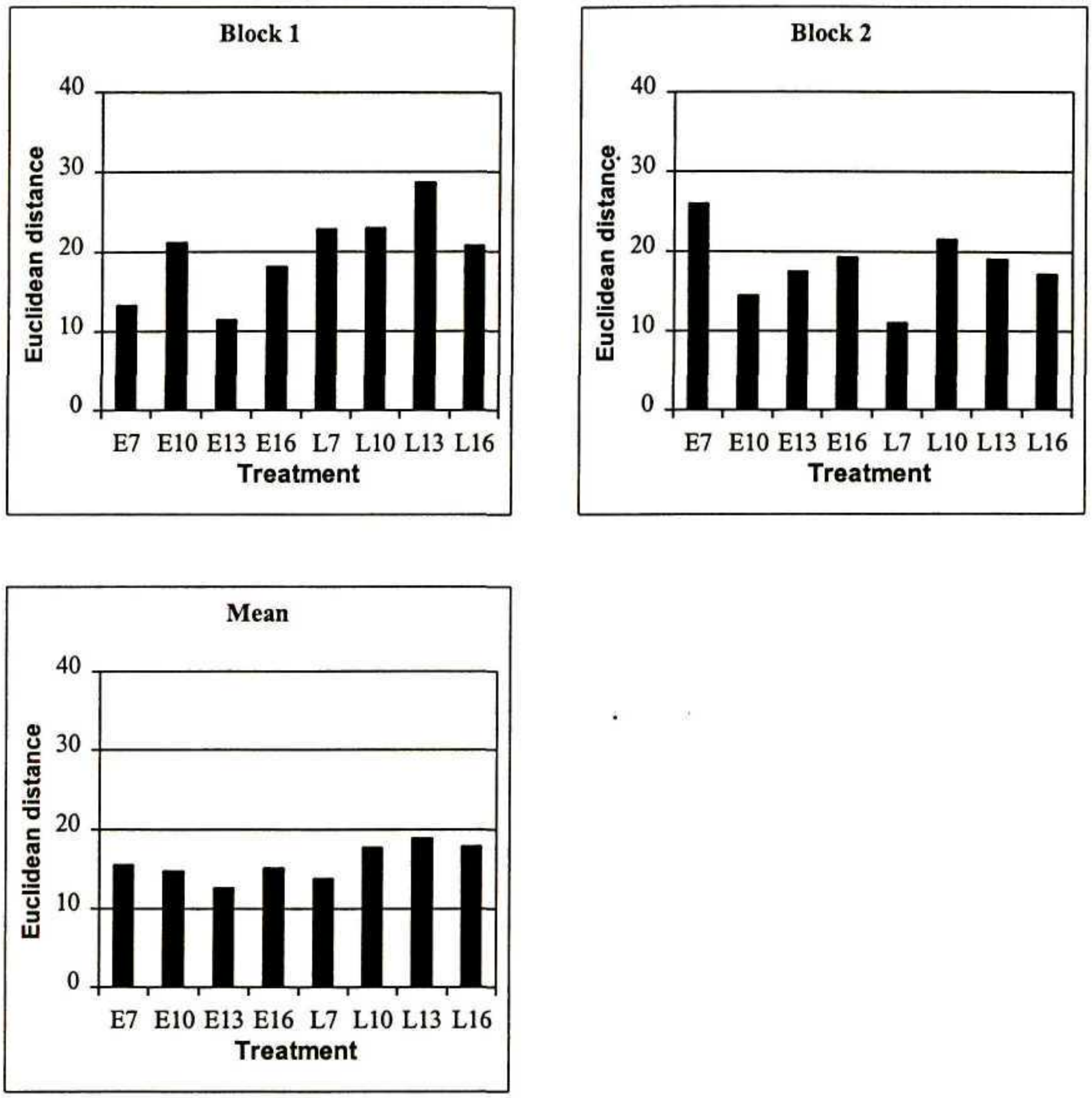


Figure 7.1 Measures of dissimilarity (Euclidean distance) between initial and final proportional species composition for all treatments in Block 1, Block 2 and for the mean of both blocks

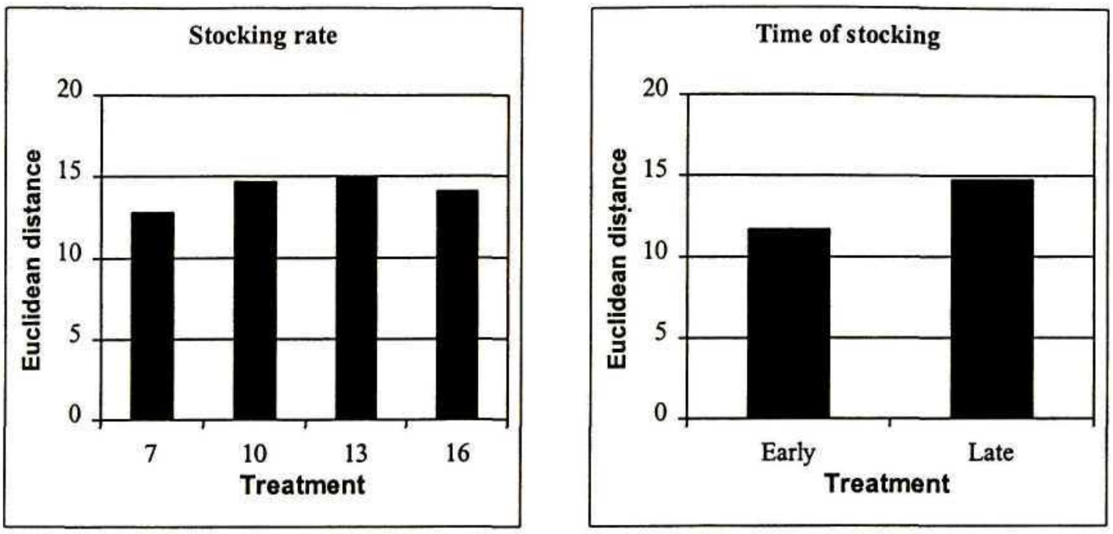


Figure 7.2 Measures of dissimilarity (Euclidean distance) between initial and final proportional species composition for the stocking rate and time of stocking treatments

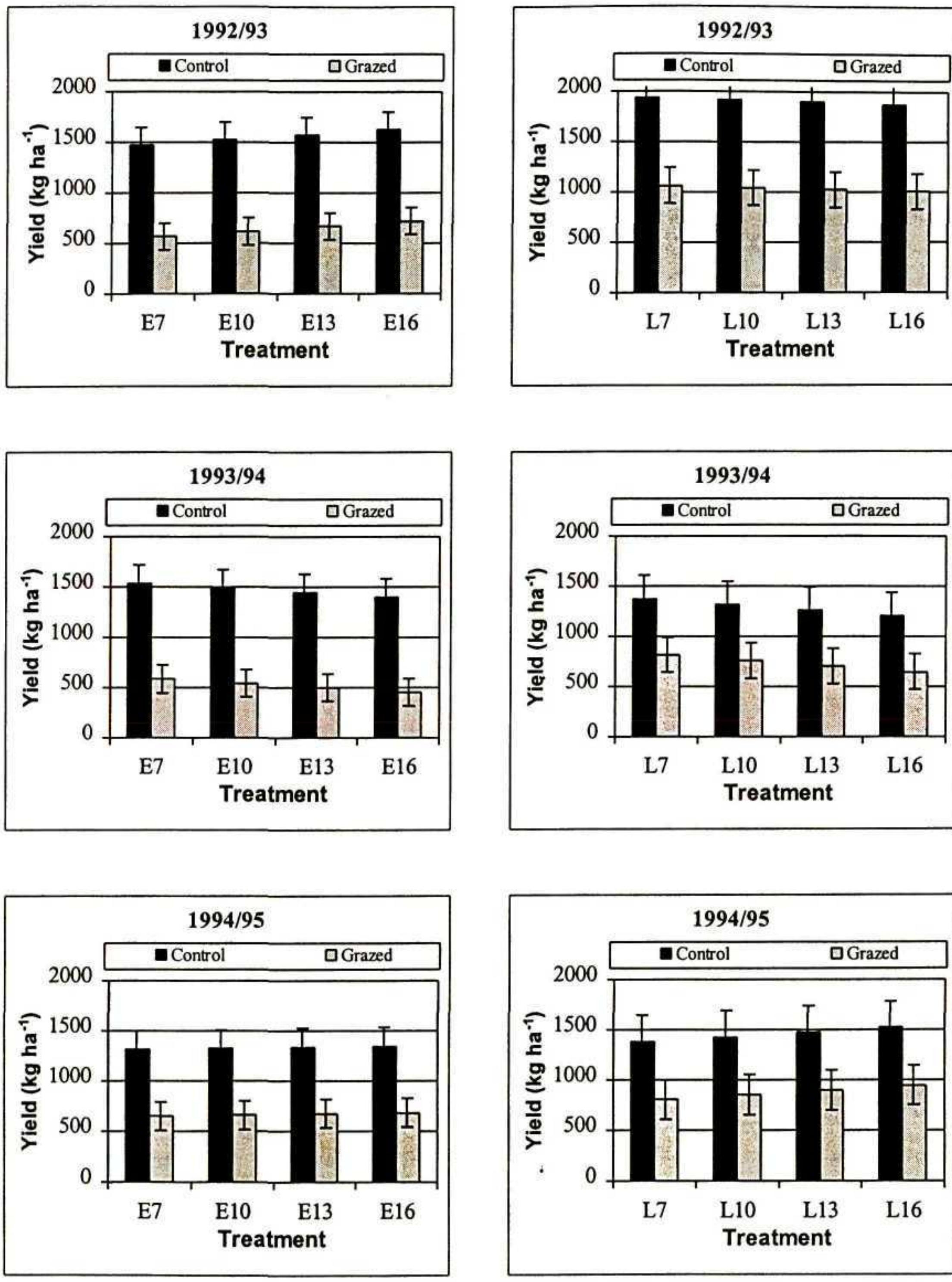


Figure 7.3 Effect of time of stocking and stocking rate on vigour (kg DM ha^{-1}) of palatable grasses (grazed) relative to the ungrazed control measured during December of the season following treatment application. The error bars represent the least significant differences ($P<0.05$)

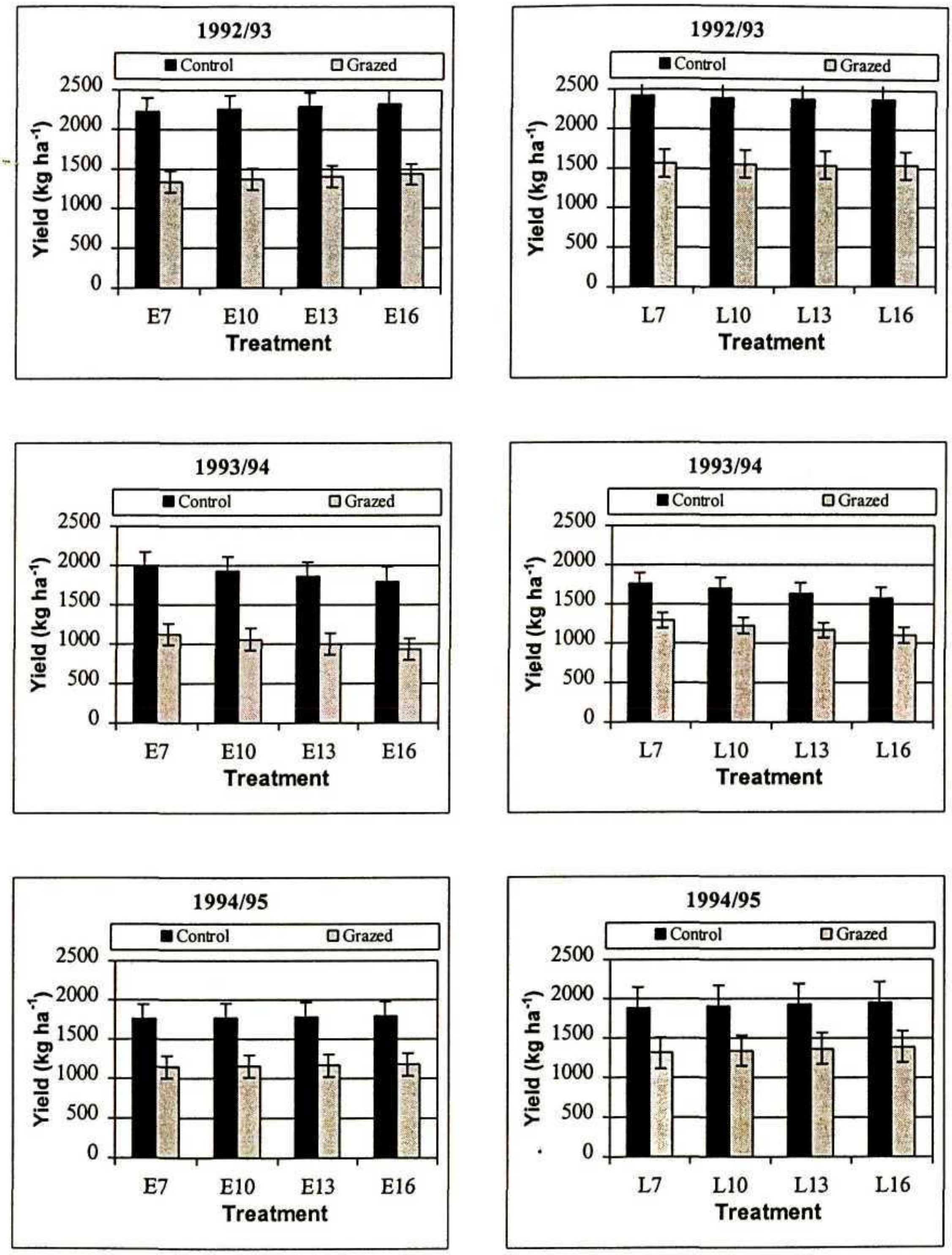


Figure 7.4 Effect of time of stocking and stocking rate on vigour (kg DM ha^{-1}) of all grass species (grazed) relative to the ungrazed control measured during December of the season following treatment application. The error bars represent the least significant differences ($P<0.05$)

CHAPTER 8

TRIAL 2: THE INFLUENCE OF VARIOUS TYPES AND FREQUENCIES OF REST ON THE PRODUCTION AND CONDITION OF SOURVELD GRAZED BY SHEEP OR CATTLE

8.1 Experimental procedure

The second trial was laid out at Nooitgedacht Agricultural Development Centre and was designed to investigate the impact of livestock type on sustainable utilisation of sourveld.

8.1.1 Experimental site

The study was conducted on Nooitgedacht Agricultural Development Centre near Ermelo (26°32'E; 29°58'S), in the North-eastern Sandy Highveld (Acocks 1975). The site has a north-easterly aspect. Nooitgedacht is located at an altitude of 1694 m above sea level. The soils are sandy and were classified as predominantly of the Wasbank form (MacVicar *et al.* 1977) with an effective depth of 500-600 mm. The Wasbank soil form comprises an orthic A horizon over an E horizon over a hard plinthic B horizon. Mean annual rainfall based on 52 year records is 719 mm (Erasmus 1992) of which most falls during the period November to April. Rainfall distribution and the rainfall for the trial period are shown in Table 8.1. Mean monthly maximum temperatures in summer and winter are 24.7 °C and 16.4 °C (Koch undated (a)). Mean monthly minimum temperatures in summer and winter are 12.9 °C and -0.1 °C respectively (Koch undated (b)). The maximum and minimum temperature details for the trial period are shown in Tables 8.2 and 8.3 respectively.

8.1.2 Procedure

Treatments involving grazing for one full growing season, followed by a full growing season rest, grazing for one and a half-growing seasons with a late growing season rest, and grazing consecutively with no growing season rest were applied. These treatments were repeated with both sheep and cattle (Table 8.4). The residual effects of the various treatments on the grass vigour were determined during following seasons.

A six ha area of fairly uniform veld which was divided into 24 paddocks of 0.25 ha each was used. Each of the six treatments was replicated four times in a randomised blocks design, so that the different treatments were applied on veld with comparable species composition (Figure 8.1). The area was rested for a full growing season before the start of the trial. A simulated rotational grazing procedure was followed using Merino ewes (mass 50 – 60 kg) and Drakensberger heifers (mass 300 – 350 kg). Grazing took place at intervals, with a four-week grazing cycle from October to April, and with all four paddocks per treatment being grazed at approximately the same stocking rate, calculated from Meissner *et al.* (1983). Livestock were placed on the paddocks for approximately one week per grazing period, for six grazing periods throughout the season. The treatments that were grazed for half a season were grazed for three periods, until the end of December. The stocking rate maintained was 1.3 ha LSU^{-1} for the duration of the grazing season in the treatments that were grazed for a full season. Assuming a 240-day grazing season, the number of LSU grazing days required was approximately 184. The treatments grazed for half a season were stocked at 1.3 ha LSU^{-1} for half of the season. The half season LSU grazing days were thus 92. The sheep and cattle treatments were carefully balanced in terms of LSU's to ensure equivalent LSU grazing days between livestock types. The livestock numbers and length of each grazing period were manipulated to balance the stocking rates. Typically 8 ewes and 2 heifers were placed on each paddock for approximately 7 days for each grazing period.

Year 1 (1992/93)

- The entire area was burnt during the last week in August using a cool fire (air temperature below 20 °C and relative humidity above 50 % (Trollope 1989)) to remove the residual dead herbage.
- Twelve exclosure cages each 875 mm square were placed in each paddock in a regular pattern so as to obtain a representative sample of the veld.

- The grazing treatments as set out in Table 8.4 were initially stocked when there was enough material to carry the stock.
- A grazing procedure with a four-week cycle (approximately seven days in and 21 days out) was followed for the duration of the grazing season for each treatment.

Year 2 (1993/94)

- Before the start of the growing season, an additional 12 exclosure cages were placed adjacent to the existing 12 cages in each paddock to create paired quadrats. The residual herbage (growth from the previous season) under each cage was clipped to a height of 20 mm above ground or tuft level and removed in order to be able to make comparisons of regrowth during the coming season.
- The relevant grazing treatments shown in Table 8.4 were applied in a similar manner to the previous year.
- The residual effects of the treatments in year 1 were recorded by conducting a DWR botanical analysis (Appendix 1) on each of four sub-quadrats (300 mm square) in each of the paired quadrats during mid-December in combination with herbage yield determinations. This gave a total of 192 sub-quadrats per treatment for the ungrazed quadrats and 192 sub-quadrats in the previously grazed quadrats.

Year 3 (1994/95)

- Before the start of the growing season, an additional 12 exclosure cages were placed adjacent to the existing 24 paired cages in each paddock. The herbage under each cage was clipped to a height of 20 mm above ground or tuft level and removed. The area was burnt during the first week of September.
- The grazing treatments were applied as in year 1.
- During mid-December DWR botanical analysis and herbage yield determinations were carried out on all quadrats under exclosure cages, to determine the effects of the treatments during the first two years.

Year 4 (1995/96)

- Before the start of the growing season, the original 12 exclosure cages in each paddock were removed from their initial positions and were placed adjacent to the existing pairs of cages on veld that was grazed during the previous season in each paddock. The herbage under all cages was clipped to a height of 20 mm above ground or tuft level and removed.

- The relevant grazing treatments shown in table 8.4 were applied in a similar manner to the previous year.
- The residual effects of the treatments in the first three years were recorded by conducting a DWR botanical analysis as described previously on four sub-quadrats (300 mm square) in each of the paired quadrats during mid-December in combination with herbage yield determinations.

Year 5 (1996/97)

- The cages placed in year 2 were removed from their original positions and placed adjacent to the remaining paired cages in each paddock on veld that that was grazed during the previous season. The herbage under all cages was clipped and removed as described above.
- The residual effects of the treatments in the first four years were recorded by conducting a DWR botanical analysis as described previously on four sub-quadrats (300 mm square) in all quadrats during mid-December in combination with herbage yield determinations.

The trial continued beyond the four years used for this study with the treatments applied as set out above.

8.1.3 Supplementary measurements

Proportional species composition surveys using the nearest plant technique (300 points per paddock) were carried out during the first season (1992/93) and during the 1996/97 season.

Table 8.1 Mean annual rainfall and rainfall for the trial period and the preceding season for Nooitgedacht Research Station (mm)

	MEAN	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
JUL	7.0	0.0	0.0	0.0	0.0	0.9	24.5
AUG	12.0	0.0	16.5	4.1	3.8	19.0	1.4
SEP	32.0	11.7	0.0	47.0	12.0	1.0	0.2
OCT	95.0	35.6	86.8	135.1	38.3	96.0	16.7
NOV	121.0	64.1	40.7	138.4	77.1	112.8	68.5
DEC	123.0	171.3	187.5	113.1	122.5	280.4	95.4
JAN	120.0	57.9	96.5	151.4	93.5	174.2	75.7
FEB	70.0	24.3	96.7	91.9	25.4	197.9	10.2
MAR	74.0	25.5	53.6	87.9	101.5	118.2	87.1
APR	40.0	23.9	18.8	13.2	66.2	61.7	34.8
MAY	16.0	0.0	11.6	2.2	0.0	0.8	0.0
JUN	9.0	0.0	0.0	0.0	0.2	0.0	8.0
TOTAL	719.0	414.3	608.7	784.3	540.5	1062.9	572.8

Table 8.2 Mean annual maximum temperature and maximum temperature for the trial period and the preceding season for Nooitgedacht Research Station (°C)

	MEAN	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
JUL	16.9	16.5	18.2	18.7	16.8	17.7	14.3
AUG	19.6	19.5	18.4	19.9	19.6	20.1	18.0
SEP	22.3	22.2	25.2	25.2	23.7	24.4	23.7
OCT	23.2	23.9	25.4	23.8	21.6	24.2	24.9
NOV	23.4	24.9	24.1	22.6	24.0	23.7	23.5
DEC	24.5	24.2	26.0	24.5	24.7	22.6	24.4
JAN	24.7	27.0	26.2	23.8	26.0	24.1	24.1
FEB	24.4	28.2	23.2	23.4	26.3	23.3	26.2
MAR	23.5	26.0	23.0	24.0	23.5	22.4	21.9
APR	21.4	25.4	22.1	21.8	21.1	19.6	20.1
MAY	19.0	21.7	21.6	20.4	18.2	17.9	18.5
JUN	16.4	18.3	17.3	16.3	17.2	17.2	17.4

Table 8.3 Mean annual minimum temperature and temperature for the trial period and the preceding season for Nooitgedacht Research Station (°C)

	MEAN	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
JUL	0.0	1.5	-0.2	1.8	-2.9	2.7	2.6
AUG	2.8	4.1	2.1	3.2	2.5	4.8	4.3
SEP	6.8	8.4	10.2	8.3	6.4	7.8	6.9
OCT	9.3	10.1	11.5	11.5	7.6	10.9	10.4
NOV	11.1	11.4	11.3	11.6	11.6	12.1	11.3
DEC	12.3	11.9	13.8	13.5	11.6	11.8	12.8
JAN	12.9	13.5	13.3	12.7	13.7	14.1	13.4
FEB	12.5	14.4	13.7	12.9	13.9	13.8	13.6
MAR	11.5	10.8	11.3	11.7	12.1	10.7	12.4
APR	7.9	9.9	9.2	7.8	8.3	8.0	6.5
MAY	3.5	3.0	5.2	2.5	4.8	5.1	4.2
JUN	-0.1	1.0	0.1	-0.4	2.4	2.8	3.0

Table 8.4 Grazing and resting schedules for the three sheep and three cattle treatments in trial 2

Trt	1992/93	1993/94	1994/95	1995/96	1996/97
Sheep 1	graze sheep	rest full season	graze sheep	rest full season	graze sheep
Sheep 2	graze sheep	graze sheep early season - rest late	graze sheep	graze sheep early season - rest late	graze sheep
Sheep 3	graze sheep	graze sheep full season	graze sheep	graze sheep full season	graze sheep
Cattle 1	graze cattle	rest full season	graze cattle	rest full season	graze cattle
Cattle 2	graze cattle	graze cattle early season - rest late	graze cattle	graze cattle early season - rest late	graze cattle
Cattle 3	graze cattle	graze cattle full season	graze cattle	graze cattle full season	graze cattle

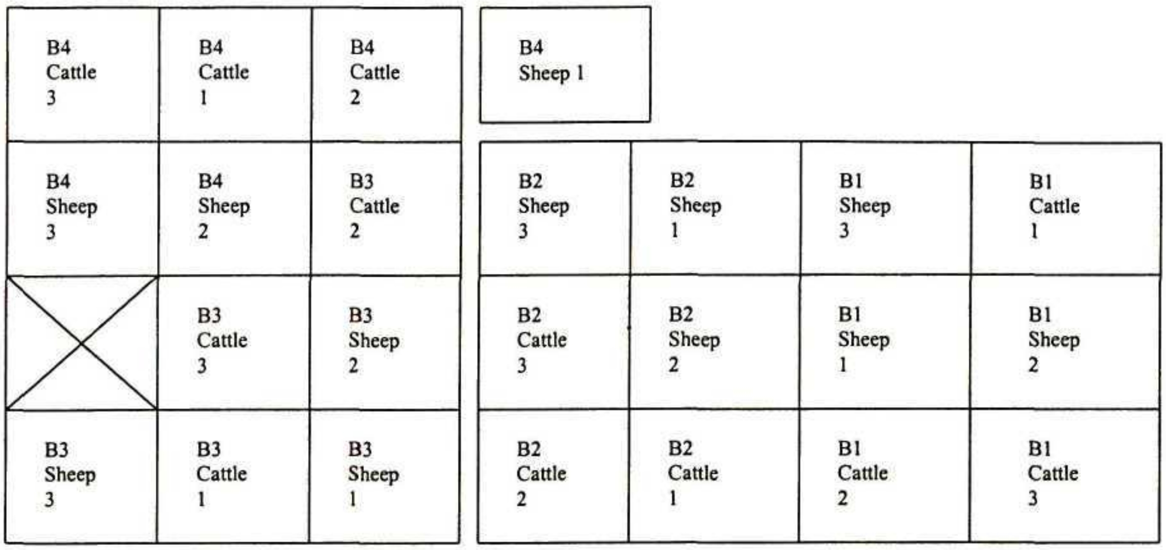


Figure 8.1 Layout of Trial 2 according to blocks (B), sheep or cattle grazing and treatments (1 – grazing and resting in alternate seasons, 2 – grazing with a half season rest in alternate years or 3 – grazing with no rest). Each paddock is 0.25 ha in size. The diagram is not drawn to scale

CHAPTER 9

TRIAL 2

THE INFLUENCE OF VARIOUS TYPES AND FREQUENCIES OF REST ON VELD VIGOUR AND SPECIES COMPOSITION OF SOURVELD GRAZED BY SHEEP OR CATTLE

9.1 Introduction

The second trial complemented the first trial in that it comprised comparisons between the effects of sheep or cattle (livestock type), as well as the effects of various rest periods (livestock movement) on veld vigour and species composition. This, together with the investigation of impact of livestock numbers in the first trial, comprises an investigation into the impact of the three variables (livestock type, numbers and movement) that can be manipulated by management. The treatments were applied as described in Chapter 8.

9.2 Effect of the grazing and resting treatments on proportional species composition

Proportional species composition surveys were carried out during the first grazing season (1992/93), and again during the 1996/97 season. The species have been grouped according to palatability classes. These groupings were based on previous experience on the site and are similar to those used by Barnes & Dempsey (1992). Note that the palatability groups differ from those in Trial 1 at Athole. The palatability of grass is usually specific to a locality and also depends on the range and amount of other species available. Experience has shown that palatability of grasses may differ between livestock types. For the purpose of this study the groupings were kept the same for both sheep and cattle. Observation of the grazing habits of the sheep and cattle on the trial revealed that the palatability classification was suitable for both types of livestock. Cattle tended to graze a wider range of species than sheep when placed under stress. This was probably more due to physical differences in the manner of grazing rather than a wider tolerance for species that sheep tend to avoid.

Examination of the proportional species composition of the veld after four seasons of the respective treatments had been applied revealed very interesting trends. The mean proportional species composition for each treatment surveyed during the first season (1992/93) and the 1996/97 season are presented in Table 9.1. Euclidean distances have been calculated (Greig-Smith 1983) as an objective measure of overall change in species composition between treatments (Figure 9.1).

9.2.1 Comparison of the effects of sheep and cattle grazing on the proportional species composition

The changes in proportional species composition due to the effect of livestock type are summarised in Table 9.2. This summary comprises the mean of the sheep treatments (treatments S1, S2 & S3) and the mean of the cattle treatments (treatments C1, C2 & C3). From Figure 9.1 it is clear that sheep grazing caused a greater change in proportional species composition than cattle grazing.

Examination of this change revealed that the sheep grazing had a detrimental effect on the proportional species composition. Examination of the palatable group of species revealed that the proportion of palatable species declined from 34.0 % to 25.4 % under sheep grazing. The proportion of palatable species increased from 39.6 % to 49.8 % under cattle grazing. Within the palatable group *Themeda triandra* was the dominant species. It declined in proportion under sheep grazing and increased under cattle grazing.

The proportion of intermediate species increased marginally under both sheep and cattle grazing. *Heteropogon contortus* declined under sheep and cattle grazing, while *Eragrostis curvula* increased substantially under both sheep and cattle.

Sheep grazing resulted in a substantial increase in the proportion of unpalatable species. In particular, the proportion of *Aristida recta* increased from 5.4 % to 23.3 %. While the total amount of *Eragrostis plana* was low, there was an increase in proportion from 0.4 % to 3.1 % under sheep grazing. In contrast, cattle grazing resulted in a marginal increase in proportion of unpalatable species from 6.7 % to 8.4 %. Of interest is the marginal increase in proportion of *Aristida recta* by 0.6 %.

The proportion of sedges declined substantially in both sheep and cattle treatments. This decline was possibly due more to environmental effects than treatment effects.

9.2.2 Comparison of the effects of grazing and resting treatments on proportional species composition

The effects of the resting treatments on proportional species composition were examined by calculating the mean species composition of the equivalent sheep and cattle treatments for the first four years (or two cycles of two years) of the trial. The treatments comprised grazing and resting in alternate years (Treatments S1 & C1), grazing during the first season followed by grazing for the first half of the second season with a half season rest every two years (Treatments S2 & C2), and grazing every season with no rest (Treatments S3 & C3). These combinations are presented in Table 9.3. Treatment 1 showed the greatest change in composition followed by treatment 2 and treatment 3 respectively (Figure 9.1).

The proportion of palatable species increased substantially in the treatments comprising graze and rest in alternate years. There was a marginal increase in proportion of palatable species in the treatment comprising a half season rest in alternate years. The treatment with no rest resulted in a decline in proportion of palatable species. The proportions of intermediate species increased in all treatment combinations. This largely reflected the substantial increase in proportion of *Eragrostis curvula* across all treatments. The proportion of unpalatable species increased in all treatment combinations, largely as a result of the increase in *Aristida recta*. The sedges declined in proportion in all treatment combinations.

9.2.3 Effects of sheep grazing in all treatment combinations on proportional species composition

The most important effects of the sheep grazing in all treatments were the decline in

Themeda triandra and the increase in *Aristida recta* (Table 9.1). The resting treatments did not appear to have much effect on these changes. The fact that sheep grazed the treatments appeared to be the overriding factor influencing the species composition. It seems that resting veld grazed by sheep does not have the same effect as resting veld grazed by cattle. Resting as a management tool is thus dependant to a large extent on livestock type in terms of the impact of the rest.

9.2.4 Effects of cattle grazing in all treatment combinations on proportional species composition

In contrast to the sheep treatments, the cattle grazing resulted in a substantial increase in *Themeda triandra* (Table 9.1). The increase was positively related to the amount of rest in the treatments. There was a marginal increase in *Aristida recta* in the two treatments including periodic rests. There was a marginal decline in *Aristida recta* in the cattle grazing treatment with no rest. The fact that cattle grazed the treatments appeared to be the overriding factor influencing the species composition.

9.3 Effect of grazing and resting treatments on veld vigour

The effects of the treatments on veld grass species vigour was determined during the December following the treatment of the previous year as described in Chapter 8. Vigour determinations were carried out for each of the first four years, or two grazing cycles. The effects of the determinations are cumulative, as the treatments were implemented on the same paddocks each year.

9.3.1 Effect of the treatments applied in 1992/93 and measured in December 1993

According to the schedule of treatments, all sheep and cattle treatments were grazed in an equivalent manner during the first year. This effectively increased the replication from four to twelve for this survey. The only comparisons that could be made at this stage were between the effects of sheep and cattle grazing. The residual effects of the sheep versus cattle treatments were measured during December 1993, midway through the following season. Yield determinations were carried out on the previously ungrazed control plots and the previously grazed plots (Table 9.4). The effects of the sheep and cattle were examined using analysis of variance (two treatments and twelve replications). The effects of livestock type, grazing versus the ungrazed control and the interaction between grazing and livestock type were examined. The effect of grazing by both sheep and cattle on the total yield of the veld was substantial (Figure 9.2). Grazing by both sheep and cattle resulted in approximately a 50 % decline in vigour the following season compared to the control ($P<0.001$). The differences between the effects of sheep and cattle grazing on total yield were not significant ($P=0.728$).

Grazing by sheep reduced the yield of the palatable species to 26 % of the control, while grazing by cattle reduced yield of the palatable species to 38 % (Table 9.4). The differences between the grazed and control plots were significant for both sheep and cattle (Figure 9.2) ($P<0.001$). The yield of the palatable species in the veld grazed by sheep was significantly ($P<0.05$) lower than the yield of the palatable species in the veld grazed by cattle. This indicates a difference in the impact of sheep grazing compared to that of cattle on the vigour of the palatable species.

The yield of the intermediate species group was lower in the veld grazed by either sheep or cattle compared with the ungrazed controls ($P<0.001$). The negative effect of the sheep grazing on the yield of this group was not as great as the negative effect of the cattle (Table 9.4). The yield of the intermediate group of species in the sheep treatments were significantly greater ($P<0.05$) than in the comparable cattle treatments. This again indicates a difference in impact of grazing between the two types of livestock.

The differences in yield between the unpalatable species in the grazed treatments compared to the ungrazed controls for both the sheep and cattle treatments (Table 9.4) were not significant (Figure 9.2).

Given the above responses of the three species groups to grazing, it is necessary to examine the impact of grazing on certain individual species within those groups. Four species, namely *Themeda triandra*, *Heteropogon contortus*, *Eragrostis curvula* and *Aristida recta* were chosen on the basis of their importance and their relatively consistent distribution across the trial site.

Themeda triandra is one of the more dominant grass species in the area, and is a desirable species for livestock production. It is often considered an indicator of veld in good condition. The yield of *Themeda triandra* was reduced to 25 % of the control in the sheep treatments and to 24 % of the control in the cattle treatments (Table 9.4). The differences in yield between the grazed and control plots were significantly different ($P<0.05$) for both sheep and cattle. The difference in yield between the treatments grazed by sheep and cattle were not significantly different (Figure 9.3). It is interesting to note that the slightly higher yield of *Themeda triandra* in the cattle control plots (270 kg DM ha^{-1} higher than in the sheep control), corresponds to a higher percentage of *Themeda triandra* (proportional composition) in the cattle treatments measured during 1992/93 (Table 9.2).

Heteropogon contortus is a common grass in the area and dominates large areas of veld. It is often considered to be a problem grass by sheep farmers because the seeds get lodged in the sheep's wool. This causes contamination of wool and often the seeds pierce the skin of the sheep. The response of *Heteropogon contortus* to grazing was slightly different to that of *Themeda triandra*. Sheep grazing reduced the yield of *Heteropogon contortus* to 49 % while cattle grazing reduced it to 37 % (Table 9.4). The yield reduction in response to grazing by both sheep and cattle was significant ($P<0.05$). The difference in response to grazing by sheep or cattle was not significantly different, although it appeared that cattle grazing caused a greater reduction in yield (Figure 9.5).

Cattle grazing caused a greater reduction in yield of *Eragrostis curvula* than sheep grazing (Table 9.4 and Figure9.3). None of the differences were, however, significant.

Aristida recta was considered the most undesirable species on the trial site with the highest potential to increase rapidly in response to any mismanagement. The response of this grass to grazing was interesting. Sheep grazing caused an increase in yield in the grazed veld compared to the control (369 %). Cattle grazing also caused an increase in yield, but of a much lower order (162 %) (Table 9.4). The yield of veld grazed by sheep was significantly less ($P<0.05$) than the yield of the control, while the cattle treatment yield was not significantly different to the control (Figure 9.3).

After grazing for one season, the effects of the sheep and cattle on veld vigour were substantial. These effects are similar to those found by Barnes & Dempsey (1992).

9.3.2 Effect of the treatments applied in 1992/93 and 1993/94 and measured in December 1994

Unlike the 1992/93 season when all treatments were grazed in an equivalent manner, the grazing and resting treatments were differentiated during the 1993/94 season. Treatment 1 was rested during the 1993/94 season, treatment 2 grazed until the end of December 1993 and treatment 3 grazed for the duration of the season. The effects measured in December 1994 were thus the effects of the first two-season treatment cycle measured during the third season. As outlined in Chapter 2, use was made of exclosure cages to create the ungrazed control plots. The design of the trial necessitated leaving the exclosure cages on the ungrazed controls for an additional season to make the measurements during the year following the treatments. These cages were then left in place for the complete season. In effect this created an additional control, which was ungrazed for two seasons (designated control 2). This created a useful opportunity for making additional comparisons between the effects of the treatments on the standard control (ungrazed for one season) and control 2.

The vigour measurements carried out in December 1994 measured the effects of the treatments in the two previous seasons. The grazed plots were grazed for two seasons according to treatment, while the control plots were ungrazed during the previous (1993/94) season. The control 2 plots were ungrazed for the duration of the trial (1992/93 & 1993/94 seasons). Treatment 1, being an alternate grazing and resting treatment, had the same treatment as the control plots during this cycle as the "grazed" plots were rested as part of the treatment. Exclosure cages had covered the control plots for the 1993/94 season, while the "grazed" plots were left open. This opportunity was used to compare any possible effects of the exclosure cages on the yield of the veld.

The effects of the treatments on the total yield as well as the yield of palatable, intermediate and unpalatable species groups are presented in Table 9.5 for the sheep treatments and Table 9.6 for the cattle treatments. The significance of the treatment effects of the above groups was examined using factorial analysis of variance with livestock type, resting treatments and controls as variables (Figure 9.4). In addition, the yields of *Themeda triandra*, *Heteropogon contortus*, *Eragrostis curvula* and *Aristida recta* were subjected to analysis of variance (Figure 9.5).

The following discussion refers to the above tables and figures. Note that the Y-axes of the graphs in Figures 9.4 & 9.5 are not all the same scale because of the large differences in yield between groups of species and individual species.

9.3.2.1 Total yield

Productivity of the veld was highest in all cases in the control 2 plots, which had been rested for two years. The yield of the control plots, which had been rested for one season, was significantly lower than the yield of the control 2 plots in all cases.

Examination of treatment 1 for both sheep and cattle revealed no significant differences between the control plots and the treatment plots. As mentioned previously these were both ungrazed during this cycle. Exclosure cages covered the control plots and the "grazed" plots left open during the rest treatment. This result indicates that the exclosure cages did not have any significant effect on the growth of the veld under the cages. The yield of the grazed plots in sheep treatment 2 was not significantly different to the control yield, while the yield in the cattle equivalent treatment was significantly lower than the control. Treatment 3, grazing for two seasons with no rest, caused a significant reduction compared to the control in both the sheep and cattle treatments ($P<0.01$).

Bearing in mind the clear results of the 1992/93 season, it seems at this stage that grazing lowers the vigour of veld (all species grouped together).

9.3.2.2 Palatable species

The control 2 yields were significantly higher than the control yields in the sheep treatments, but not in the cattle treatments. The control and grazed treatments are again equivalent in treatment 1 for both sheep and cattle. Examination of treatments 2 and 3 reveal interesting trends. It seems that the less rest applied, the lower the yield of the palatable species in both sheep and cattle treatments. Examining both the treatment gradients and the gradient from control 2 through the control to the grazed plots reveal this trend.

Sheep appear to have a greater detrimental effect on the yield of the palatable species than cattle. This difference can be seen through all the treatments.

9.3.2.3 Intermediate species

The patterns emerging for the intermediate group of species are virtually the opposite of the patterns observed for total yield and yield of the palatable species. In the sheep treatments the control 2 plots were consistently the lowest yielding plots in all treatments, followed by the control and the grazed plots. (The control and grazed plots in treatment 1 were again equivalent.)

The differences between the cattle treatments were not significant.

9.3.2.4 Unpalatable species

The reaction of the unpalatable species group to the treatments is less clear, probable due to the relatively low yields of the group as whole. It does seem at this stage that the yield of the unpalatable group was higher in the sheep treatments in comparison to the equivalent cattle treatments.

9.3.2.5 *Themeda triandra*

On an individual species level the productivity of species between treatments varies somewhat more than in the case of the species groups. The approach taken in interpreting the data has been to use each treatment's control 2 and control yields as the basis for evaluating the treatment effects. Comparisons between treatments were made cautiously, bearing in mind the absolute differences in yield between treatments.

The effect of decreasing the amount of rest on the treatments clearly lowered the productivity of *Themeda triandra*, while the greater negative impact of sheep grazing in relation to cattle grazing is also clear. The equivalence of the control and grazed treatments in treatment 1 can also clearly be seen.

9.3.2.6 *Heteropogon contortus*

The yield of *Heteropogon contortus* was consistently higher in the control 2 plots than the control or grazed plots. There were significant differences in treatment 3 for both sheep and cattle. In the sheep treatment 3, control 2 yielded significantly higher than the grazed plots with the control between the two. In the cattle treatment 3, control 2 was significantly higher than both the control and the grazed plots.

9.3.2.7 *Eragrostis curvula*

No clear trends emerged from the *Eragrostis curvula* data during this cycle, although there was a tendency for the yield to increase in sheep treatment 3 with declining amount of rest.

9.3.2.8 *Aristida recta*

The yield of *Aristida recta* was generally low over the trial site, which makes the data relatively variable. An interesting trend at this stage is the high yield in sheep treatments 1 & 2 in the control and grazed plots relative to control 2.

9.3.3 Effect of the treatments applied in the first three seasons and measured in December 1995

All treatments were grazed in an equivalent manner during the 1992/93 season by sheep and cattle. During the 1993/94 season the grazing treatments were applied according to the grazing schedule to complete the first two-year cycle. The 1994/95 season was the start of the second two-year cycle, and consequently all treatments were again grazed in an equivalent manner by sheep and cattle respectively after burning during spring. The measurement of the residual effects of the treatments was thus the cumulative effect of three consecutive years of treatments. Treatment 1 was grazed in 1992/93, rested in 1993/94 and grazed 1994/95. Treatment 2 was grazed in 1992/93, grazed for the first half of 1993/94 and grazed in 1994/95. Treatment 3 was grazed during all three seasons. The veld under the control and control 2 exclosure cages thus received an equivalent treatment for Treatment 1.

The effects of the treatments on the total yield as well as the yield of palatable, intermediate and unpalatable species groups are presented in Table 9.7 for the sheep treatments and Table 9.8 for the cattle treatments. The significance of the treatment effects of the above groups was examined using analysis of variance (Figure 9.6). In addition, the yields of *Themeda triandra, Heteropogon contortus, Eragrostis curvula* and *Aristida recta* were subjected to analysis of variance (Figure 9.7).

9.3.3.1 Total yield

The yields of all of the grazed plots were significantly lower than the control and control 2, except for the sheep treatment 1 where there was no significant difference. The yield of the cattle grazed plots and the sheep grazed plots were similar, apart from sheep treatment 1, which was significantly higher. The yield of the cattle controls and control 2 plots were higher than the corresponding sheep plots. The negative effect of grazing on veld yield is again shown in the cumulative effects of three year's treatment.

9.3.3.2 Palatable species

Very clear differences between the effects of sheep and cattle on the yield of the palatable species can be seen. The yields of the control 2 yields in the cattle treatments are significantly higher than the sheep control 2 plots. The control plots show a similar trend. Within the sheep plots, it is clear that the yield of the grazed plots drops from treatment 1 to treatments 2 & 3. The yield of the treatment 3 control is significantly lower than the control 2 yield. The control in this treatment was grazed for two years, followed by a rest, which formed the ungrazed control during the third season. The control 2 was grazed only for the first year of the trial, followed by two years as an ungrazed control.

In the cattle treatments, the yield of palatable species on the treatment 3 control was significantly lower than the controls on treatments 1 & 2. The yield of the grazed plots was lower than the control 2 and control plots. The yield of the palatable species on the cattle treatments was significantly higher than on the sheep treatments (P<0.001). It appears that sheep grazing, irrespective of the resting treatment, had a greater negative impact than cattle grazing on the yield of the palatable species.

9.3.3.3 Intermediate species

The yield of the intermediate species was higher in the sheep treatments than in the cattle treatments (P<0.001). This is probably a reflection of the avoidance of these species by sheep unless they are forced to graze them. It is also possibly due to reduced competition from the palatable species, which were grazed more severely on the sheep treatments.

9.3.3.4 Unpalatable species

Although the yield of the unpalatable species fluctuates, two trends emerge. The yield of the unpalatable species is generally higher in the sheep treatments than the cattle treatments (P<0.05). Also, the yield of the grazed plots is higher than the yield of the control and control 2 plots.

9.3.3.5 *Themeda triandra*

The yield of *Themeda triandra* in the sheep treatments was lower than the cattle treatments (P<0.001). Within the sheep treatments, yield dropped with declining amounts of rest. A similar trend could be seen in the cattle treatments. *Themeda triandra* is thus negatively affected by grazing, and particularly sheep grazing.

9.3.3.6 *Heteropogon contortus*

The only obvious trend to emerge (although not significant) was that in both the sheep and cattle grazed treatments, the yield of *Heteropogon contortus* declined with decreasing amount of rest.

9.3.3.7 *Eragrostis curvula*

The yield of *Eragrostis curvula* was generally higher under sheep grazing than under cattle grazing.

9.3.3.8 *Aristida recta*

The yield of *Aristida recta* was higher in the sheep grazing treatments than in the cattle grazing treatments. Examination of the sheep grazing treatments revealed that the yield of *Aristida recta* increased with decreasing amounts of rest, while in the cattle grazing treatments the trend appeared to be opposite.

9.3.4 Effect of the treatments applied in the first four seasons and measured in December 1996

The 1995/96 season was the second season of the second two-year cycle. Treatment 1 was thus rested, treatment 2 grazed for the first half of the season and treatment 3 was grazed for the full season. Over the duration of the trial treatment 1 was grazed and rested in alternate seasons for two cycles. Treatment 2 had two late season rests in alternate years. Treatment 3 was grazed for the four seasons in succession.

The effects of the treatments on the total yield as well as the yield of palatable, intermediate and unpalatable species groups are presented in Table 9.9 for the sheep treatments and Table 9.10 for the cattle treatments. The significance of the treatment effects of the above groups was examined using analysis of variance (Figure 9.8). In addition, the yields of *Themeda triandra*, *Heteropogon contortus*, *Eragrostis curvula* and *Aristida recta* were subjected to analysis of variance (Figure 9.9). For Treatment 1, the veld under the grazed and control exclosure cages received equivalent treatments in this cycle.

9.3.4.1 Total yield

After four years of treatments applied using sheep and cattle, the total yield of the cattle treatments was higher than the yield of the sheep treatments ($P<0.001$) (Table 9.11). Treatment 3 yields were lower than treatment 1 & 2 for both sheep and cattle (Figure 9.8), particularly on the grazed plots.

The obvious trends emerging are that veld yield is depressed under sheep grazing compared to cattle, and that periodic resting increases yield. These trends have been consistent over the four years of the trial period, and are consistent with the results obtained in the first trial in this study, as well as with the results obtained by Barnes & Dempsey 1992).

9.3.4.2 Palatable species

The patterns emerging within the palatable species group are similar to the patterns noted for total yield, only more pronounced. The yield of the palatable species was significantly higher under cattle grazing than sheep grazing after four years (Table 9.11). It is clear that sheep grazing substantially impacts the yield of the palatable species relative to cattle grazing. It is also clear that resting boosts the yield of the palatable species.

9.3.4.3 Intermediate species

The yield of the intermediate species group was significantly higher in the sheep treatments than in the cattle treatments (Table 9.11). Increasing the resting frequency seemed to increase the yield of the intermediate species in both sheep and cattle treatments.

9.3.4.4 Unpalatable species

The main trend to emerge within the unpalatable species group was the significantly higher yield in the sheep treatments relative to the cattle treatments (Table 9.11).

9.3.4.5 *Themeda triandra*

The effect of the treatments on the yield of *Themeda triandra* was interesting, as was examination of the yield of the controls relative to the grazed plots. After four years of grazing, the yield of *Themeda triandra* on the sheep treatments was 51.6 % of the *Themeda triandra* yield on the cattle plots (Table 9.11). It was also clear that less rest depresses the yield in both sheep and cattle treatments.

9.3.4.6 *Heteropogon contortus*

No clear, significant trends emerged regarding the effect of the treatments on the yield of *Heteropogon contortus*.

9.3.4.7 *Eragrostis curvula*

Grazing by sheep seemed to increase the yield of *Eragrostis curvula* relative to the control and control 2 plots. Within the cattle treatments, grazing did not change the yield relative to the control and control 2 plots.

9.3.4.8 *Aristida recta*

The yield of *Aristida recta* was significantly higher in the sheep treatments than in the cattle treatments (Table 9.11). Within the sheep treatments, the yield was the lowest in treatment 1, comprising grazing and resting in alternate years. In sheep treatments 2 & 3 the yield of *Aristida recta* on the grazed plots was significantly higher than on the control and control 2 plots. The yield of *Aristida recta* was highest in treatment 2 for both sheep and cattle treatments. Within the cattle treatments differences in yield were insignificant, but it appeared that treatment 3 had the lowest yield of *Aristida recta*.

9.4 Discussion

The two methods used for evaluating impact of grazing on veld, namely proportional species composition and vigour measurements, again gave valuable insight into the livestock / grass interaction in a similar manner to the first trial. In this case, the species composition data included four full seasons of treatment application, which should make the data more reliable than the species composition data from the first trial.

Sheep grazing caused a negative change in species composition relative to cattle grazing, irrespective of the resting treatment applied. There appears to be an interaction between livestock type and resting treatment, with a rest applied to veld grazed by sheep having a different effect to rest applied to veld grazed by cattle. This is an extremely important point, as it is now obvious that a growing season rest applied to veld grazed by sheep can not compensate for the negative effects of sheep grazing on species composition. Veld grazed by sheep and rested in alternate years declined in species composition compared to veld grazed by cattle with no rest. In other words, the "best" sheep treatment was more detrimental to the veld condition than the "worst" cattle treatment.

The measurement of vigour again provided a short-term measure of the impact of grazing. Evaluation of the impact of the first season's treatments reveals that it would have been possible to predict with some accuracy what the long-term effect on species composition would be. This could provide a significant break-through in determining impact of grazing and other management variables in a short period.

The negative effect of sheep grazing on the total veld yield, yield of the palatable species group and in particular the yield of *Themeda triandra* provides valuable insight into the impact of grazing. In addition, the beneficial effects of rest were demonstrated both in the treatments and in the controls. The increase in vigour of the unpalatable species group, in particular *Aristida recta*, further reinforced the fact that grazing of a species has a negative impact on its vigour. Species that are not grazed are placed at an advantage in that their vigour increases relative to the same species in the ungrazed control. This certainly appeared true for the species under investigation in this study. Also, the difference between the effects of sheep and cattle on the vigour of the unpalatable group highlighted the difference in the type of livestock. Sheep once again emerge as having a serious negative impact on veld vigour.

The close agreement between the impacts measured in terms of species composition and vigour increase the value of the results, and allows for confident formulation of grazing management recommendations.

Table 9.1 Proportional species composition of all treatments surveyed during the 1992/93 season (season 1), and again during the 1996/97 season (season 5). A full list of species names and abbreviations is tabled in Appendix 2

Treatment	S1		S2		S3		C1		C2		C3	
Season	1	5	1	5	1	5	1	5	1	5	1	5
Palatable species												
Andspp	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
Braser	0.0	0.0	0.0	0.6	0.0	0.1	0.0	0.0	0.0	2.0	0.0	0.1
Digtri	1.0	0.4	4.2	0.6	4.2	0.9	4.8	5.1	1.9	3.2	7.0	8.2
Hyphir	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.2	0.0
Moncer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Setsph	0.6	0.8	1.2	0.4	0.2	0.1	0.7	0.4	0.6	1.1	0.6	0.3
Thetri	23.4	19.2	22.9	16.7	18.9	17.2	22.7	33.8	34.3	41.7	24.9	27.7
Trileu	5.7	6.4	8.6	7.0	11.1	5.8	7.4	9.7	3.2	5.2	10.4	10.7
Sub-total	30.6	26.8	37.1	25.3	34.3	24.1	35.7	49.1	40.1	53.3	43.0	47.0
Intermediate species												
Braspp	0.1	0.2	0.2	0.4	0.2	0.2	0.5	0.4	0.2	0.4	0.1	0.0
Cynspp	0.6	0.1	0.0	0.1	0.2	0.2	0.7	0.0	0.1	0.0	0.2	0.2
Digmon	1.7	0.2	1.7	0.5	2.2	0.5	1.0	0.3	1.1	0.9	2.0	1.7
Elimut	2.8	2.1	2.6	4.2	3.7	4.0	2.1	2.8	3.0	1.6	5.2	2.9
Eracap	0.9	0.2	1.7	0.0	1.7	0.0	0.7	0.1	0.6	0.3	1.1	0.2
Erachl	0.0	2.3	0.1	1.7	0.2	0.9	0.0	0.6	0.0	0.9	0.1	0.5
Eracur	9.8	17.3	7.4	18.6	8.0	15.9	7.6	17.2	8.6	14.9	7.1	12.9
Erarac	1.3	2.7	1.8	7.3	2.1	8.2	0.7	2.6	1.1	2.1	1.3	6.1
Eraspp	0.3	0.0	0.1	0.0	0.2	0.4	0.7	0.3	0.3	0.1	0.1	0.3
Harfal	1.2	1.7	1.7	3.3	2.3	3.5	1.6	1.8	1.2	2.2	1.6	3.4
Hetcon	9.3	5.4	15.6	5.1	17.2	5.8	14.1	9.2	14.0	8.5	13.8	9.5
Koecap	0.0	0.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.2
Miccaf	0.7	0.2	0.9	0.1	0.7	0.8	1.0	0.4	0.5	0.4	0.7	1.0
Traspi	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.2
Sub-total	28.8	32.7	33.9	41.5	38.8	40.6	30.5	35.7	30.7	32.4	33.4	39.1
Unpalatable species												
Arirec	6.4	25.1	5.3	22.4	4.4	22.5	3.5	5.4	4.7	6.2	6.8	5.3
Cymplu	0.2	0.9	0.4	0.2	1.3	0.8	1.1	0.4	1.2	0.1	0.4	0.2
Eragum	0.8	1.1	0.1	1.1	0.4	1.6	0.4	0.5	0.5	0.2	0.2	0.5
Dihfil	0.1	0.0	0.0	0.2	0.1	0.6	0.3	0.0	0.1	0.0	0.0	0.0
Erapla	0.9	4.4	0.3	3.3	0.1	1.7	0.4	1.8	0.3	3.0	0.0	1.6
Pannat	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0
Sub-total	8.4	31.4	6.2	27.3	6.3	27.2	5.9	8.0	6.9	9.5	7.4	7.6
Other	0.0	0.4	0.0	0.7	0.0	1.0	0.0	0.5	0.0	0.3	0.0	0.9
Forbs	3.8	0.5	4.7	2.0	4.0	1.0	7.3	3.1	3.2	0.8	6.6	2.0
Sedges	28.0	5.4	18.1	2.6	16.5	4.8	20.6	3.2	18.9	3.0	9.6	2.3
Scirpus	0.3	2.7	0.0	0.7	0.0	1.4	0.0	0.4	0.2	0.7	0.0	1.0
Total	100	100	100	100	100	100	100	100	100	100	100	100

Table 9.2 Proportional species composition surveyed during the 1992/93 season (season 1), and again during the 1996/97 season (season 5) for the sheep (Treatments S1, S2 & S3) and cattle treatments (Treatments C1, C2 & C3). A full list of species names and abbreviations is tabled in Appendix 2

Treatment	Sheep		Cattle	
Season	1	5	1	5
Palatable species				
Andapp	0.1	0.0	0.0	0.1
Braser	0.0	0.2	0.0	0.7
Digtri	3.1	0.6	4.6	5.5
Hyphir	0.0	0.0	0.1	0.0
Moncer	0.0	0.0	0.0	0.0
Setsph	0.7	0.4	0.6	0.6
Thetri	21.7	17.7	27.3	34.4
Trileu	8.5	6.4	7.0	8.5
Sub-total	34.0	25.4	39.6	49.8
Intermediate species				
Braspp	0.2	0.2	0.3	0.3
Cynspp	0.3	0.1	0.3	0.1
Digmon	1.9	0.4	1.4	1.0
Elimut	3.1	3.4	3.4	2.4
Eracap	1.4	0.1	0.8	0.2
Erachl	0.1	1.6	0.0	0.7
Eracur	8.4	17.3	7.7	15.0
Erarac	1.7	6.1	1.1	3.6
Eraspp	0.2	0.1	0.4	0.2
Harfal	1.8	2.9	1.5	2.5
Hetcon	14.1	5.5	14.0	9.1
Koecap	0.0	0.1	0.0	0.1
Miccaf	0.7	0.4	0.7	0.6
Traspi	0.0	0.0	0.0	0.1
Sub-total	33.8	38.3	31.6	35.8
Unpalatable species				
Arirec	5.4	23.3	5.0	5.6
Cymplu	0.6	0.6	0.9	0.2
Eragum	0.4	1.3	0.4	0.4
Dihfil	0.1	0.3	0.1	0.0
Erapla	0.4	3.1	0.2	2.1
Pannat	0.1	0.0	0.1	0.0
Sub-total	7.0	28.6	6.7	8.4
Other	0.0	0.7	0.0	0.6
Forbs	4.2	1.1	5.7	2.0
Sedges	20.9	4.3	16.3	2.8
Scirpus	0.1	1.6	0.1	0.7
Total	100	100	100	100

Table 9.3 Proportional species composition surveyed during the 1992/93 season (season 1), and again during the 1996/97 season (season 5) for the treatments comprising grazing and resting in alternate years (Treatments S1 & C1), grazing during the first season of a two year cycle followed by grazing for the first half of the second season with a half season rest (Treatments S2 & C2), and grazing every season with no rest (Treatments S3 & C3). A full list of species names and abbreviations is tabled in Appendix 2

Treatment	Graze / rest		Graze / graze & rest		Graze – no rest	
Season	1	5	1	5	1	5
Palatable species						
Andapp	0.0	0.0	0.1	0.0	0.0	0.0
Braser	0.0	0.0	0.0	1.3	0.0	0.1
Digtri	2.9	2.7	3.0	1.9	5.6	4.6
Hyphir	0.1	0.0	0.0	0.0	0.1	0.0
Moncer	0.0	0.0	0.0	0.0	0.0	0.0
Setsph	0.6	0.6	0.9	0.7	0.4	0.2
Thetri	23.0	26.5	28.6	29.2	21.9	22.4
Trileu	6.5	8.0	5.9	6.1	10.8	8.2
Sub-total	33.2	38.0	38.6	39.3	38.7	35.6
Intermediate species						
Braspp	0.3	0.3	0.2	0.4	0.2	0.1
Cynspp	0.6	0.0	0.0	0.0	0.2	0.2
Digmon	1.3	0.3	1.4	0.7	2.1	1.1
Elimut	2.5	2.5	2.8	2.9	4.5	3.4
Eracap	0.8	0.1	1.1	0.2	1.4	0.1
Erachl	0.0	1.5	0.0	1.3	0.1	0.7
Eracur	8.7	17.2	8.0	16.7	7.5	14.4
Erarac	1.0	2.6	1.5	4.7	1.7	7.2
Eraspp	0.5	0.2	0.2	0.0	0.2	0.4
Harfal	1.4	1.8	1.5	2.8	2.0	3.5
Hetcon	11.7	7.3	14.8	6.8	15.5	7.7
Koecap	0.0	0.1	0.0	0.1	0.0	0.1
Miccaf	0.8	0.3	0.7	0.2	0.7	0.9
Traspi	0.0	0.0	0.0	0.0	0.0	0.1
Sub-total	29.7	34.2	32.3	37.0	36.1	39.9
Unpalatable species						
Arirec	4.9	15.2	5.0	14.3	5.6	13.9
Cymplu	0.6	0.7	0.8	0.1	0.9	0.5
Eragum	0.6	0.8	0.3	0.7	0.3	1.0
Dihfil	0.2	0.0	0.0	0.1	0.0	0.3
Erapla	0.7	3.1	0.3	3.2	0.0	1.6
Pannat	0.1	0.0	0.1	0.0	0.0	0.0
Sub-total	7.2	19.7	6.5	18.4	6.9	17.4
Other	0.0	0.4	0.0	0.5	0.0	1.0
Forbs	5.6	1.8	4.0	1.4	5.3	1.5
Sedges	24.3	4.3	18.5	2.8	13.1	3.5
Scirpus	0.2	1.5	0.1	0.7	0.0	1.2
Total	100	100	100	100	100	100

Table 9.4 Mean yields (kg DM ha^{-1}) of the veld in December 1993 after grazing by sheep and cattle during the 1992/93 season or resting (control). A full list of species names and abbreviations is tabled in Appendix 2.

	Sheep		Grazed as	Cattle		Grazed as
	Control	Grazed	% of control	Control	Grazed	% of control
Palatable species						
Andapp	10.5	1.1	11	0.0	0.2	0
Braser	8.3	0.0	0	0.6	0.0	0
Digtri	223.6	63.3	28	166.7	99.1	59
Hyphir	1.1	0.0	0	4.6	0.0	0
Moncer	0.8	0.2	21	0.0	0.0	0
Setsph	2.5	0.5	20	0.5	0.2	44
Thetri	1707.2	429.5	25	2004.1	676.3	34
Trileu	251.0	89.6	36	212.0	121.9	58
Subtotal	2205.0	584.2	26	2388.5	897.8	38
Intermediate species						
Allsem	9.6	0.7	7	5.1	0.0	0
Braspp	0.0	0.2	0	0.0	0.5	0
Cynspp	0.0	3.1	0	0.0	0.0	0
Digmon	48.7	56.1	115	20.4	34.0	166
Elimut	105.0	91.3	87	93.8	66.4	71
Eracap	30.7	11.5	38	6.0	20.1	333
Erachl	14.1	21.7	153	1.4	14.9	1071
Eracur	404.7	361.2	89	393.0	278.3	71
Erarac	61.6	51.7	84	55.9	28.2	50
Eraspp	0.0	0.6	0	5.7	1.1	20
Harfal	43.9	58.7	134	39.0	24.5	63
Hetcon	614.0	303.8	49	637.3	238.4	37
Koecap	1.9	0.9	48	0.0	0.0	0
Miccaf	2.4	3.5	149	1.2	3.0	253
Traspi	13.6	0.0	0	5.8	2.6	45
Subtotal	1350.1	965.1	71	1264.5	712.1	56
Unpalatable species						
Arirec	49.5	182.8	369	50.0	81.2	162
Cymplu	95.1	29.9	31	90.0	39.9	44
Dihfil	3.1	0.0	0	0.0	3.5	0
Eragum	35.9	12.5	35.	5.5	20.4	369
Erapla	10.0	33.5	336	0.0	8.5	0
Pannat	38.0	1.6	4	4.4	0.3	6
Other	12.0	0.0	0.0	0.6	0.2	27.0
Sedges	47.0	84.1	179	68.0	55.3	81
Scirpus	0.3	9.0	2872	3.7	3.8	102
Subtotal	290.9	353.4	121	222.3	213.1	96
Total	3846.4	1902.7	49	3875.4	1822.9	47

Table 9.5 Mean yields (kg DM ha^{-1}) of the veld in December 1994 after grazing by sheep during the previous two seasons as well as the yields of the control (C) and Control 2 which comprises a two-year rest (C·2). A full list of species names and abbreviations is tabled in Appendix 2

	Sheep T1			Sheep T2			Sheep T3		
	C 2	C	Grazed	C 2	C	Grazed	C 2	C	Grazed
Palatable									
Andapp	6.9	2.4	5.6	10.9	5.0	0.0	0.0	0.0	0.0
Digeri	13.0	0.9	7.2	0.0	0.0	0.0	0.0	0.0	0.0
Digtri	41.8	31.6	46.5	103.2	47.0	37.2	184.5	67.4	37.1
Moncer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Setsph	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.3	0.0
Thetri	685.8	377.1	368.2	603.7	420.6	315.1	521.9	505.2	253.4
Trileu	97.9	37.0	43.0	164.8	82.7	64.4	218.7	113.4	83.2
Subtotal	845.4	449.1	470.6	882.6	555.7	416.7	925.0	686.3	373.7
Intermediate species									
Allsem	11.3	0.0	0.0	0.0	0.0	0.0	12.2	0.0	0.0
Braspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Cynspp	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Digmon	7.3	4.4	5.5	27.8	30.3	25.0	16.8	26.8	47.9
Elimut	46.2	56.3	59.7	40.5	46.7	89.9	26.6	51.8	76.4
Eracap	10.5	10.8	5.3	4.0	8.0	12.3	5.8	6.3	10.1
Erachl	0.0	0.8	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Eracur	169.4	186.8	164.5	56.7	79.1	81.8	90.3	125.5	168.7
Erarac	25.2	110.8	133.0	32.4	149.2	190.7	35.9	72.6	95.3
Eraspp	2.4	0.0	4.9	0.8	0.3	0.0	1.2	1.5	1.1
Harfal	9.5	19.9	8.7	33.1	47.3	37.4	51.6	43.2	36.9
Hetcon	97.9	90.2	120.2	182.0	122.6	155.2	233.8	173.2	115.3
Koecap	0.0	0.0	0.0	0.0	0.2	0.0	4.1	0.0	0.0
Miccaf	1.3	2.9	6.1	1.2	11.0	1.3	1.0	0.6	13.1
Traspi	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Subtotal	381.1	482.8	511.5	378.6	494.8	593.7	479.4	501.4	565.0
Unpalatable species									
Arirec	15.5	37.6	37.6	22.1	36.0	36.5	6.5	8.2	18.7
Ctecon	0.0	0.0	0.0	12.6	0.0	0.0	0.0	0.0	0.0
Cymplu	25.2	49.1	31.4	67.2	19.7	43.6	39.9	44.9	63.0
Dihfil	17.9	25.5	12.4	0.0	0.0	1.5	8.3	0.6	0.3
Eragum	10.7	20.7	20.2	0.6	13.6	0.5	0.0	0.0	1.5
Erapla	3.4	14.1	7.4	1.0	0.0	5.5	0.0	0.0	0.0
Pannat	0.0	0.0	2.1	1.0	0.0	0.0	3.8	0.0	0.0
Other	1.2	0.2	0.8	10.7	1.0	0.0	3.3	0.4	0.0
Sedges	18.9	35.8	20.5	6.9	14.3	15.7	8.3	15.3	16.7
Scirpus	0.0	2.7	10.2	0.0	0.0	0.0	0.0	5.0	1.0
Subtotal	92.8	185.6	142.6	122.1	84.6	103.2	70.2	74.5	101.2
Total	1319.4	1117.5	1124.7	1383.3	1135.1	1113.6	1474.6	1262.2	1039.9

Table 9.6 Mean yields (kg DM ha^{-1}) of the veld in December 1994 after grazing by cattle during the previous two seasons as well as the yields of the control (C) and Control 2 which comprises a two-year rest (C˙2). A full list of species names and abbreviations is tabled in Appendix 2

	Cattle T1			Cattle T2			Cattle T3		
	C 2	C	Grazed	C 2	C	Grazed	C 2	C	Grazed
Palatable									
Andapp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digeri	0.8	0.0	6.1	0.4	0.0	0.0	0.0	3.9	0.0
Digtri	62.8	43.6	79.2	77.2	69.5	35.0	137.9	111.7	125.6
Moncer	0.0	0.0	0.0	0.0	0.0	3.5	1.5	0.0	0.0
Setsph	0.3	3.2	1.2	0.0	0.8	1.8	0.0	0.0	0.4
Thetri	861.6	699.5	698.9	1027.5	855.9	664.1	685.4	618.7	318.7
Trileu	76.9	88.3	99.6	49.2	21.6	14.0	97.3	95.3	63.1
Subtotal	1002.5	834.6	884.9	1154.3	947.8	718.4	922.1	829.6	507.8
Intermediate species									
Allsem	23.0	2.9	14.6	0.6	0.0	0.0	0.0	0.0	0.0
Braspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digmon	1.8	4.8	1.7	7.0	17.6	22.8	15.9	21.0	15.0
Elimut	31.6	42.8	13.2	26.6	29.3	70.2	37.7	35.5	88.8
Eracap	0.5	0.6	1.8	4.5	31.9	19.1	4.6	12.0	17.7
Erachl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eracur	67.3	59.6	90.7	102.2	103.3	131.2	76.8	50.6	89.0
Erarac	16.2	63.9	61.8	18.2	28.5	34.9	28.7	75.2	66.7
Eraspp	0.0	0.3	0.0	0.0	0.8	1.9	0.0	0.0	1.2
Harfal	26.7	12.3	23.0	22.6	3.2	1.9	33.1	25.4	32.0
Hetcon	220.4	158.3	184.2	168.3	158.3	139.2	285.7	153.7	84.5
Koecap	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
Miccaf	0.0	0.0	0.5	0.3	0.6	0.5	0.3	0.0	0.3
Traspi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	387.4	345.5	391.6	350.4	373.6	421.5	483.5	373.5	399.1
Unpalatable species									
Arirec	8.6	19.4	10.1	16.2	10.4	6.6	14.7	7.7	3.8
Ctecon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymplu	66.7	46.4	41.6	39.8	26.0	29.4	51.0	8.1	19.5
Dihfil	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eragum	0.0	0.0	0.3	2.0	18.2	1.1	0.0	5.7	6.5
Erapla	0.6	1.3	0.0	5.4	3.4	8.3	0.0	0.0	0.0
Pannat	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Other	1.5	0.0	0.0	0.0	0.0	0.0	1.2	0.2	0.0
Sedges	21.7	19.6	24.2	17.9	9.2	12.5	5.4	9.3	13.0
Scirpus	0.0	0.0	0.0	17.8	1.5	5.0	0.0	0.0	0.0
Subtotal	99.6	95.8	76.3	99.3	68.6	62.9	72.2	31.0	42.8
Total	1489.5	1275.9	1352.7	1604.0	1390.0	1202.8	1477.8	1234.1	949.6

Table 9.7 Mean yields (kg DM ha^{-1}) of the veld in December 1995 after grazing by sheep during the previous three seasons as well as the yields of the control (C) and Control 2 which comprises a two-year rest (C'2). A full list of species names and abbreviations is tabled in Appendix 2

	Sheep T1			Sheep T2			Sheep T3		
	C 2	C	Grazed	C 2	C	Grazed	C 2	C	Grazed
Palatable									
Andapp	4.1	0.0	0.0	15.4	1.3	0.0	0.0	0.0	0.0
Digeri	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Digtri	51.5	48.4	90.7	100.1	58.7	12.8	140.9	105.1	9.0
Setsph	2.4	2.2	0.0	0.9	2.2	0.4	3.4	0.0	2.1
Thetri	836.0	963.1	695.4	746.7	703.3	284.8	696.0	468.2	208.7
Trileu	89.5	79.7	72.6	173.3	130.8	47.2	227.7	105.8	93.1
Subtotal	983.6	1093.3	858.7	1036.3	896.7	345.3	1068.0	679.1	312.8
Intermediate species									
Allsem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Braspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Cynspp	2.5	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Digmon	0.6	0.3	4.9	47.1	29.9	19.6	38.0	56.5	63.4
Elimut	74.9	131.7	106.8	109.8	196.1	268.6	94.4	185.2	136.5
Eracap	13.6	1.0	22.0	13.1	18.9	2.2	12.7	6.6	1.0
Erachl	36.6	8.9	4.3	0.8	0.0	6.3	1.8	2.0	26.5
Eracur	259.9	180.6	262.2	72.8	109.7	313.2	145.4	223.6	174.9
Erarac	32.6	63.0	77.4	84.7	85.6	154.6	43.5	87.0	128.3
Eraspp	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Harfal	42.6	35.5	28.8	109.3	48.9	64.2	51.2	77.0	95.4
Hetcon	373.1	513.0	353.4	407.9	488.6	237.5	420.2	442.6	199.3
Koecap	1.9	1.8	0.8	0.9	0.4	0.0	0.0	0.0	0.0
Miccaf	0.8	1.2	0.0	2.2	0.0	0.0	0.0	5.6	3.3
Traspi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	838.9	937.2	860.6	848.7	978.1	1066.6	807.3	1086.7	828.5
Unpalatable species									
Arirec	82.3	40.2	69.0	21.3	31.6	124.1	29.2	33.0	133.3
Cymplu	53.4	40.6	108.2	61.0	42.8	28.7	51.9	85.7	118.2
Dihfil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eragum	34.0	20.0	38.5	35.8	7.6	6.0	0.0	10.7	10.0
Erapla	39.9	4.4	111.7	0.0	5.2	4.1	0.0	0.0	0.0
Pannat	21.7	0.0	0.0	0.0	1.7	0.0	0.7	0.0	0.0
Other	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sedges	2.2	1.7	8.3	4.3	2.5	12.3	2.4	0.5	3.1
Scirpus	2.0	25.8	28.3	0.0	0.0	0.0	7.4	0.9	31.3
Subtotal	242.9	132.6	364.1	122.5	91.3	175.2	91.6	130.9	295.9
Total	2065.4	2163.1	2083.3	2007.6	1966.1	1587.0	1966.9	1896.6	1437.1

Table 9.8 Mean yields (kg DM ha^{-1}) of the veld in December 1995 after grazing by cattle during the previous three seasons as well as the yields of the control (C) and Control 2 which comprises a two-year rest (C·2). A full list of species names and abbreviations is tabled in Appendix 2

	Cattle T1			Cattle T2			Cattle T3		
	C 2	C	Grazed	C 2	C	Grazed	C 2	C	Grazed
Palatable									
Andapp	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Digeri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Digtri	107.6	129.2	44.6	50.4	86.2	16.6	197.3	171.1	95.0
Setsph	2.2	3.6	1.7	3.9	0.4	7.0	1.4	0.0	8.3
Thetri	1232.4	1441.6	566.0	1947.0	1585.2	792.2	1258.3	972.0	632.2
Trileu	179.4	166.6	201.7	68.5	36.7	51.8	252.2	160.6	209.6
Subtotal	1521.5	1741.0	814.4	2069.7	1708.5	867.6	1709.2	1304.5	945.1
Intermediate species									
Allsem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9
Braspp	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.3
Cynspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.2
Digmon	1.5	0.0	2.9	23.6	16.0	30.1	8.2	11.4	28.0
Elimut	59.4	29.4	74.4	96.7	95.1	140.1	71.2	120.3	98.8
Eracap	4.3	4.5	0.8	6.8	3.1	6.2	1.1	2.6	4.9
Erachl	4.1	2.4	12.4	2.2	6.0	24.5	0.8	11.0	3.9
Eracur	124.7	120.2	143.6	83.1	188.7	163.8	19.0	31.8	55.4
Erarac	46.5	25.0	39.7	8.7	16.2	31.3	43.8	64.5	58.0
Eraspp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harfal	52.6	27.9	18.8	12.3	0.0	30.3	36.1	79.5	48.4
Hetcon	470.5	514.7	379.4	376.1	339.8	312.6	366.5	238.0	212.2
Koecap	0.0	0.0	0.0	17.8	3.3	0.0	1.8	0.3	0.0
Miccaf	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.9
Traspi	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
Subtotal	763.6	724.0	672.1	627.3	668.3	739.1	558.5	560.9	520.0
Unpalatable species									
Arirec	6.9	61.0	88.4	28.3	11.5	20.5	9.5	13.4	35.1
Cymplu	82.3	38.0	109.0	43.2	115.1	98.4	25.6	8.7	23.8
Dihfil	24.9	0.0	0.0	0.0	0.0	0.0	12.3	2.4	4.2
Eragum	0.0	1.8	6.2	25.4	0.0	6.0	0.0	12.8	12.9
Erapla	1.4	0.0	0.0	0.0	1.1	2.0	0.0	0.0	1.9
Pannat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0
Other	0.0	12.1	0.7	0.0	0.0	0.0	3.9	0.7	0.0
Sedges	3.9	0.0	6.7	3.8	4.1	0.0	3.2	1.3	5.1
Scirpus	0.0	0.8	0.0	0.8	1.1	12.6	0.0	0.0	1.3
Subtotal	119.3	113.6	211.0	101.5	132.9	139.5	54.5	41.9	84.3
Total	2404.4	2578.7	1697.5	2798.5	2509.8	1746.3	2322.2	1907.4	1549.4

Table 9.9 Mean yields (kg DM ha^{-1}) of the veld in December 1996 after grazing by sheep during the previous four seasons as well as the yields of the control (C) and Control 2 which comprises a two year rest (C·2). A full list of species names and abbreviations is tabled in Appendix 2

	Sheep T1			Sheep T2			Sheep T3		
	C 2	C	Grazed	C 2	C	Grazed	C 2	C	Grazed
Palatable									
Andapp	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0
Braser	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Digtri	102.9	24.7	13.5	136.2	95.5	94.8	127.8	65.2	23.1
Hyphir	6.6	0.0	4.1	53.9	0.0	1.4	7.5	0.0	0.0
Moncer	7.8	0.6	1.2	4.6	0.0	0.0	0.0	0.0	0.0
Setsph	11.4	19.0	12.9	7.6	8.0	7.4	13.7	9.0	2.4
Thetri	532.3	308.2	358.6	407.9	246.7	209.6	250.2	213.7	101.8
Trileu	119.2	102.8	89.4	204.5	69.8	70.4	194.8	156.4	70.1
Subtotal	780.3	455.3	479.7	814.6	428.4	383.6	594.1	444.3	197.4
Intermediate species									
Cynspp	10.6	2.1	2.0	1.4	5.0	0.0	3.9	14.3	0.0
Digmon	0.0	26.8	13.2	17.4	21.6	25.3	31.5	28.6	26.1
Elimut	105.6	106.7	123.6	129.6	122.5	92.0	105.1	61.3	80.0
Eracap	6.9	0.9	1.5	8.9	19.0	4.9	17.7	6.5	15.7
Eracur	179.4	238.8	306.4	95.9	170.0	283.6	74.8	167.1	199.4
Erarac	63.2	98.2	69.6	118.2	223.7	103.5	80.7	160.6	182.6
Harfal	28.8	30.0	4.6	32.8	27.0	67.6	17.3	40.1	62.4
Hetcon	225.5	171.5	143.8	363.8	149.4	102.8	424.7	194.3	174.6
Koecap	10.0	4.7	2.2	2.3	0.0	0.0	1.2	0.0	0.0
Miccaf	0.9	1.6	0.0	2.6	1.7	0.3	13.8	14.1	18.8
Traspi	0.6	0.0	1.2	0.8	0.0	2.4	2.8	0.0	0.0
Subtotal	631.5	681.2	668.1	773.7	739.9	682.5	773.4	687.0	759.6
Unpalatable species									
Arirec	55.9	89.7	64.2	121.5	184.0	253.9	62.8	109.7	166.6
Cymplu	0.3	0.0	2.9	8.4	16.9	15.6	13.4	9.0	0.0
Dihfil	25.7	3.6	0.9	0.8	6.5	0.0	0.0	0.0	0.0
Eragum	34.4	30.1	39.9	0.0	0.0	0.0	0.0	0.0	2.1
Erapla	27.4	82.3	50.7	9.5	3.6	12.3	8.2	1.7	24.8
Pannat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Sedges	3.0	14.5	11.4	8.4	4.6	1.4	0.7	2.5	11.0
Scirpus	116.3	146.3	137.8	0.8	23.8	5.6	22.7	33.2	60.0
Subtotal	263.1	366.5	317.9	149.4	239.3	288.8	107.8	156.2	264.6
Total	1674.8	1503.0	1465.7	1737.6	1407.6	1354.9	1475.2	1287.5	1221.5

Table 9.10 Mean yields (kg DM ha^{-1}) of the veld in December 1996 after grazing by cattle during the previous four seasons as well as the yields of the control (C) and Control 2 which comprises a two year rest (C.2). A full list of species names and abbreviations is tabled in Appendix 2

	Cattle T1			Cattle T2			Cattle T3		
	C 2	C	Grazed	C 2	C	Grazed	C 2	C	Grazed
Palatable									
Andapp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Braser	0.0	0.0	0.0	0.0	0.0	0.9	0.0	8.6	0.0
Digtri	268.1	210.3	103.0	100.7	70.3	43.5	296.2	224.6	128.2
Hyphir	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moncer	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Setsph	17.9	9.4	13.8	45.5	47.4	30.1	5.5	16.5	1.5
Thetri	805.6	663.6	535.5	875.5	666.0	387.7	481.9	449.6	221.4
Trileu	275.0	202.6	194.6	127.2	152.7	77.4	279.3	281.6	182.6
Subtotal	1366.6	1086.0	847.7	1148.9	936.4	539.6	1062.9	980.9	533.7
Intermediate species									
Cynspp	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Digmon	14.1	2.2	0.0	40.0	28.7	34.8	10.3	5.4	42.1
Elimut	34.9	45.5	32.7	67.2	62.4	53.2	61.3	58.2	55.2
Eracap	5.6	0.0	2.3	28.5	6.2	52.5	1.5	6.3	24.0
Eracur	199.6	203.8	202.5	379.2	354.5	400.1	131.4	115.5	150.2
Erarac	12.8	46.5	78.2	36.8	68.9	53.1	63.1	118.2	208.0
Harfal	0.7	4.7	65.5	13.6	2.2	10.4	36.3	9.3	10.6
Hetcon	290.7	219.3	246.1	159.1	105.4	126.7	258.3	238.0	146.0
Koecap	0.0	7.7	1.0	0.0	0.0	0.0	0.0	7.4	0.0
Miccaf	0.6	1.2	6.3	0.0	0.0	0.5	3.7	4.5	8.3
Traspi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	559.0	530.9	635.3	724.5	628.3	731.2	566.0	562.7	644.4
Unpalatable species									
Arirec	36.0	69.1	65.4	103.7	85.5	61.4	3.4	19.6	20.3
Cymplu	1.6	1.7	9.7	6.5	13.1	11.7	7.7	22.9	10.2
Dihfil	0.0	0.0	1.2	6.7	0.0	0.0	0.0	0.0	0.0
Eragum	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0
Erapla	0.0	0.8	0.0	23.1	60.4	36.5	0.0	5.9	0.5
Pannat	0.0	1.5	0.0	2.1	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	2.5	0.0	10.1	0.0	0.7	0.0
Sedges	14.6	16.4	36.0	10.1	11.8	47.3	0.7	4.6	32.3
Scirpus	44.1	1.9	31.9	103.6	158.5	223.3	62.4	193.4	58.0
Subtotal	96.4	91.4	144.2	258.3	329.2	390.3	79.3	247.1	121.2
Total	2022.1	1708.4	1627.2	2131.7	1893.8	1661.1	1708.2	1790.7	1299.4

Table 9.11 Comparison of the sheep and cattle treatments in terms of the total yield, yield of the three palatability groups and the yield of four individual species after four years of treatment application (kg DM ha^{-1}). A full list of species names and abbreviations is tables in Appendix 2

	Sheep	Cattle	Significance	Sheep veld yield as % of cattle veld yield
Total	1459	1761	P<0.001	83
Palatable	509	945	P<0.001	86
Intermediate	711	620	P<0.01	115
Unpalatable	171	77	P<0.001	222
Thetri	292	565	P<0.001	52
Hetcon	217	199	P=0.423	109
Eracur	191	237	P=0.102	81
Arirec	123	52	P<0.001	237

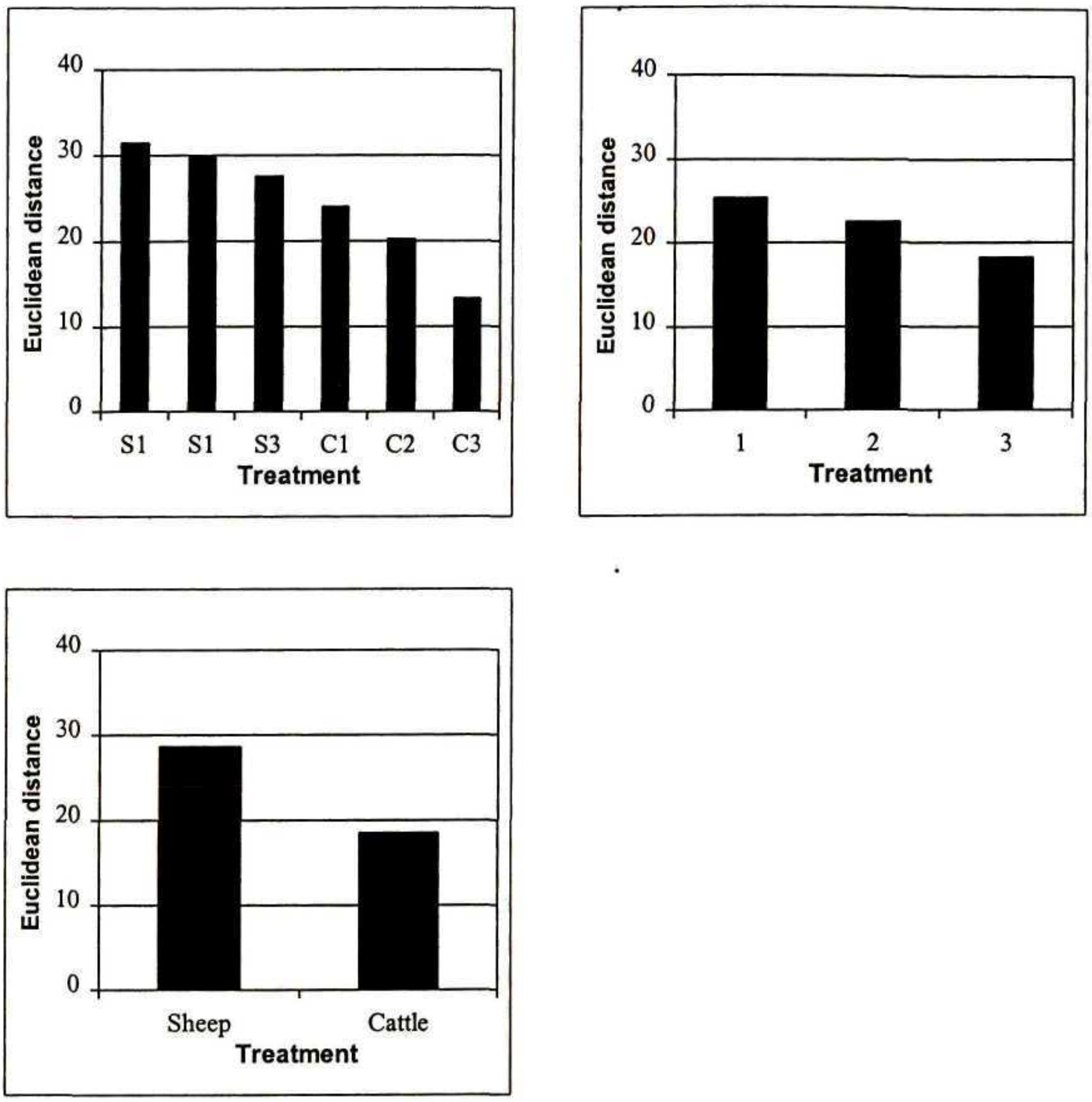


Figure 9.1 Measures of dissimilarity (Euclidean distance) between initial and final proportional species composition for all sheep (S) and cattle (C) treatments (1 – graze and rest in alternate years, 2 – half season rest in alternate years, 3 – grazing with no rest), for the sheep and cattle treatments grouped together and for the sheep and cattle with the treatments grouped together

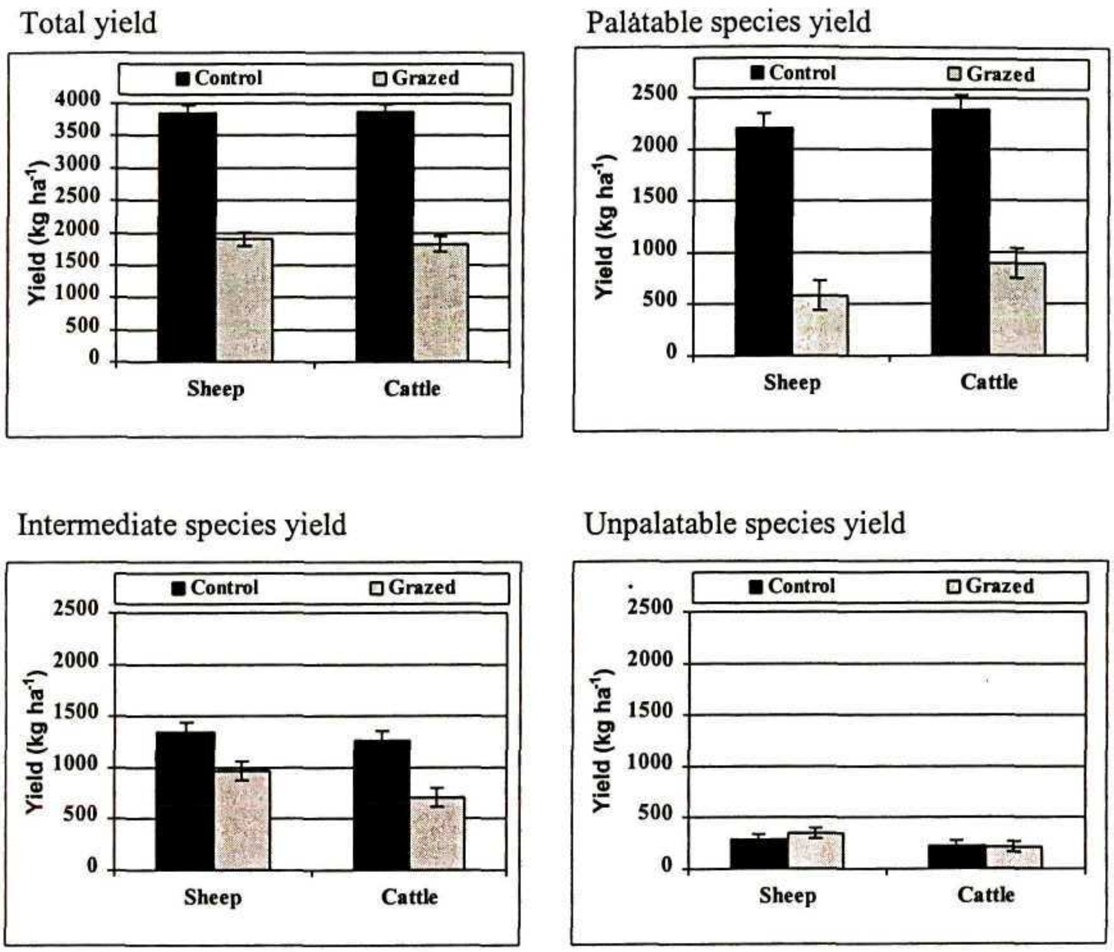


Figure 9.2 Effects of sheep and cattle grazing during the 1992/93 season on the total yields and the yield of the palatable, intermediate and unpalatable species of the control and grazed plots measured during December 1993. The error bars represent the least significant differences ($P<0.05$)

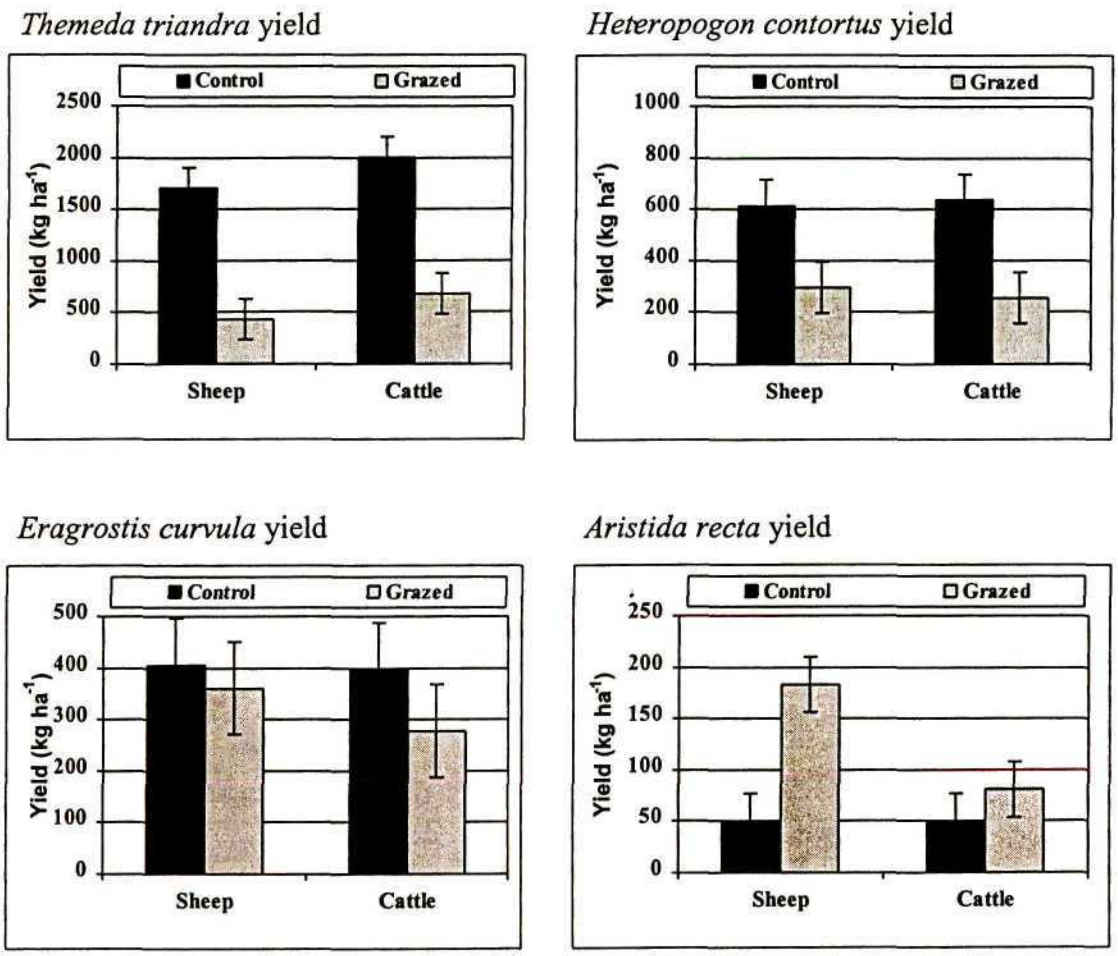


Figure 9.3 Effects of sheep and cattle grazing during the 1992/93 season on the yield of *Themeda triandra, Heteropogon contortus, Eragrostis curvula* and *Aristida recta* of the control and grazed plots measured during December 1993. The error bars represent the least significant differences ($P<0.05$)

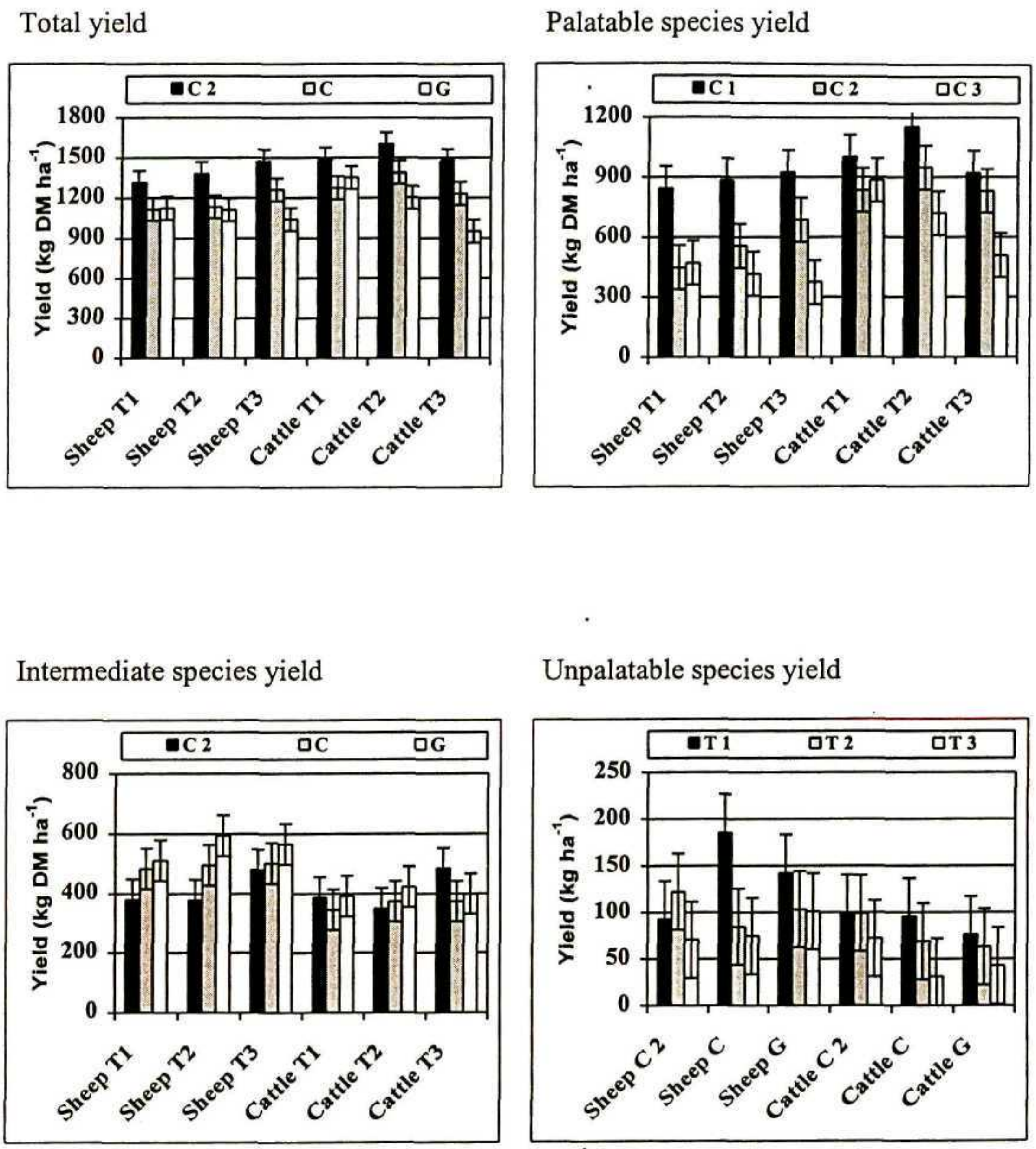


Figure 9.4 Effects of sheep and cattle grazing during the first two seasons on the total yields and the yield of the palatable, intermediate and unpalatable species of the control (C), control 2 (C2 – ungrazed for two years) and grazed plots measured during December 1994. The error bars represent the least significant differences ($P<0.05$)

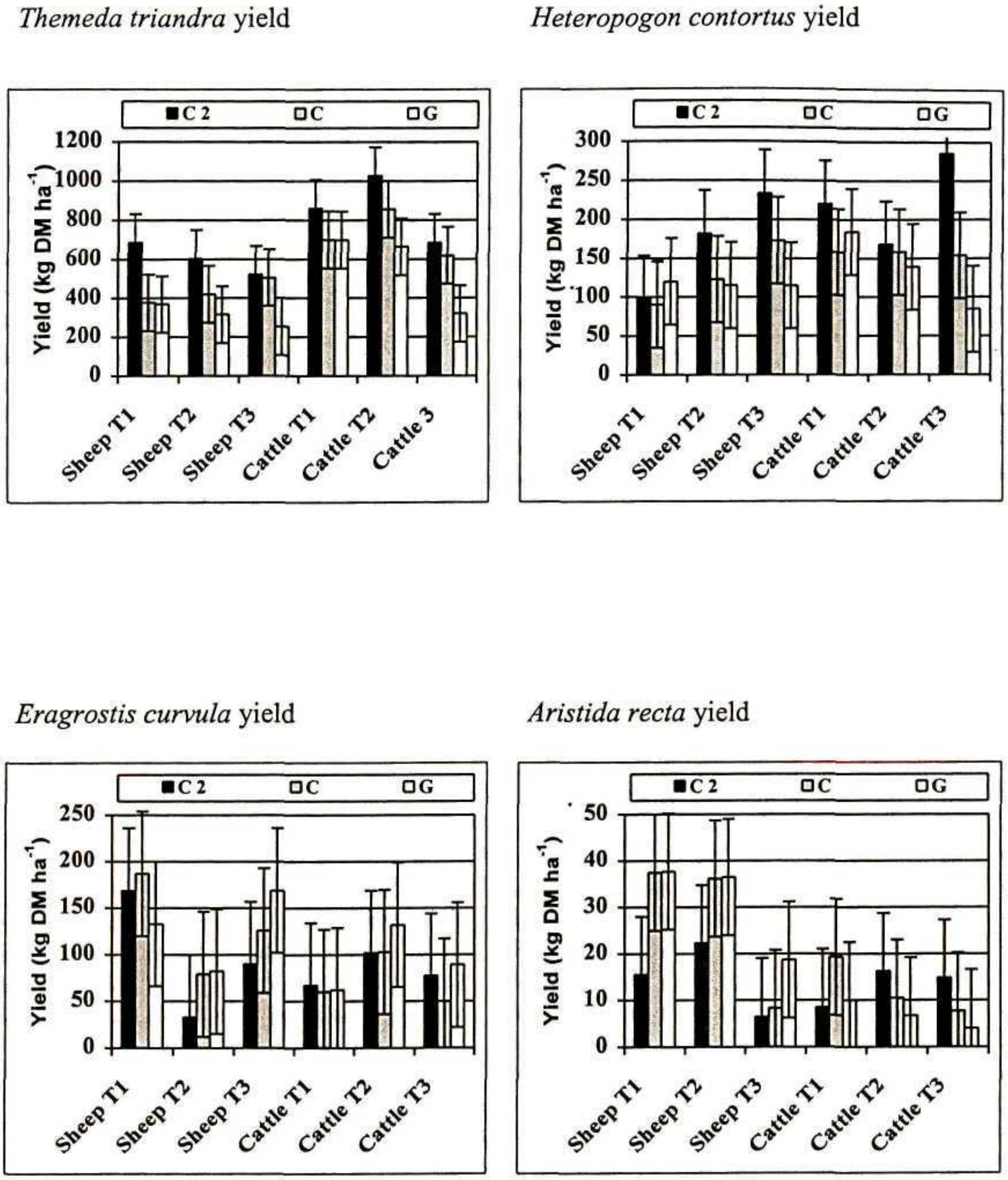


Figure 9.5 Effects of sheep and cattle grazing during the first two seasons on the yield of *Themeda triandra*, *Heteropogon contortus*, *Eragrostis curvula* and *Aristida recta* of the control (C), control 2 (C2 – ungrazed for two years) and grazed plots measured during December 1994. The error bars represent the least significant differences ($P<0.05$)

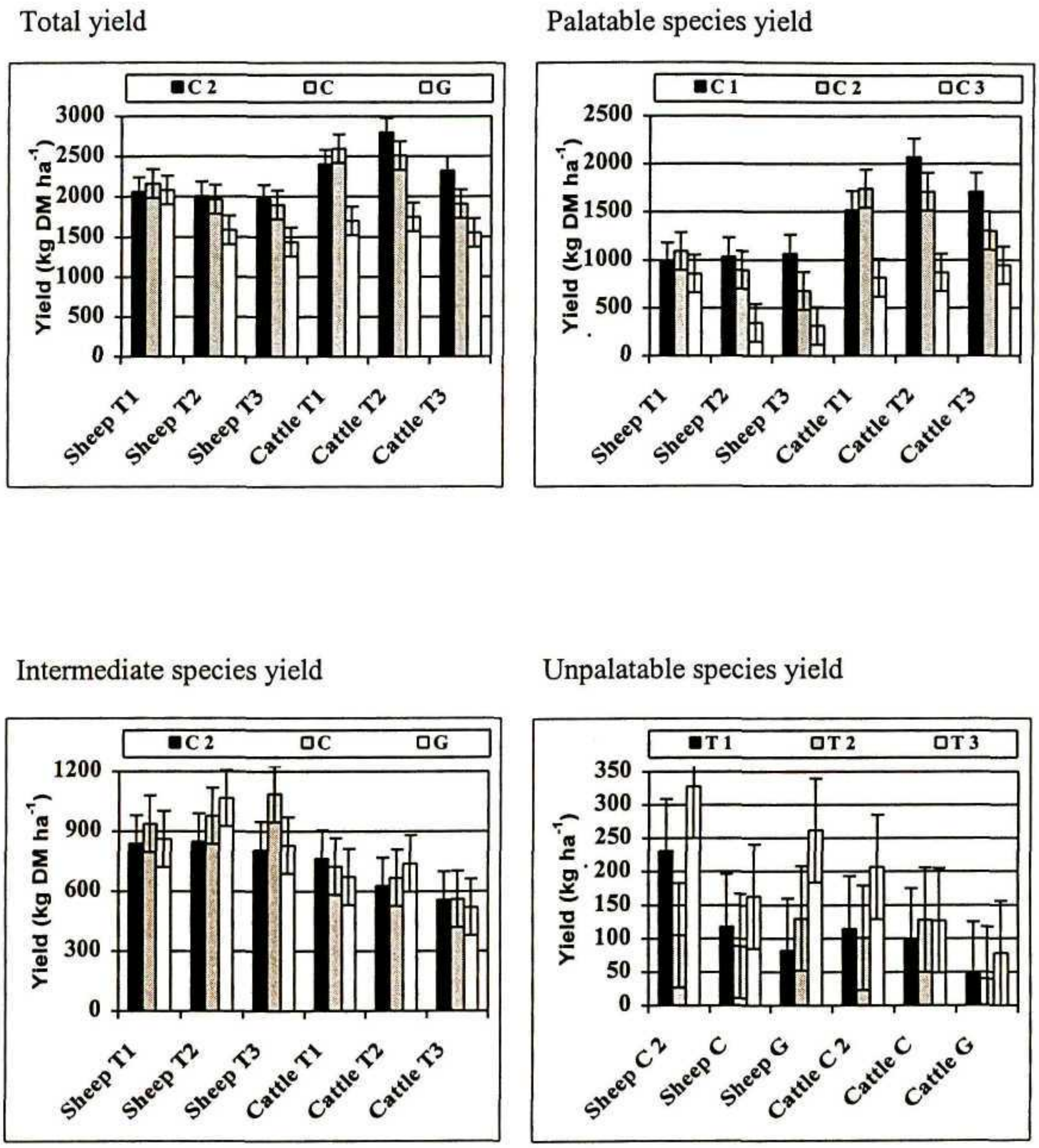


Figure 9.6 Effects of sheep and cattle grazing during the first three seasons on the total yields and the yield of the palatable, intermediate and unpalatable species of the control (C), control 2 (C2 – ungrazed for two years) and grazed plots measured during December 1995. The error bars represent the least significant differences ($P<0.05$)

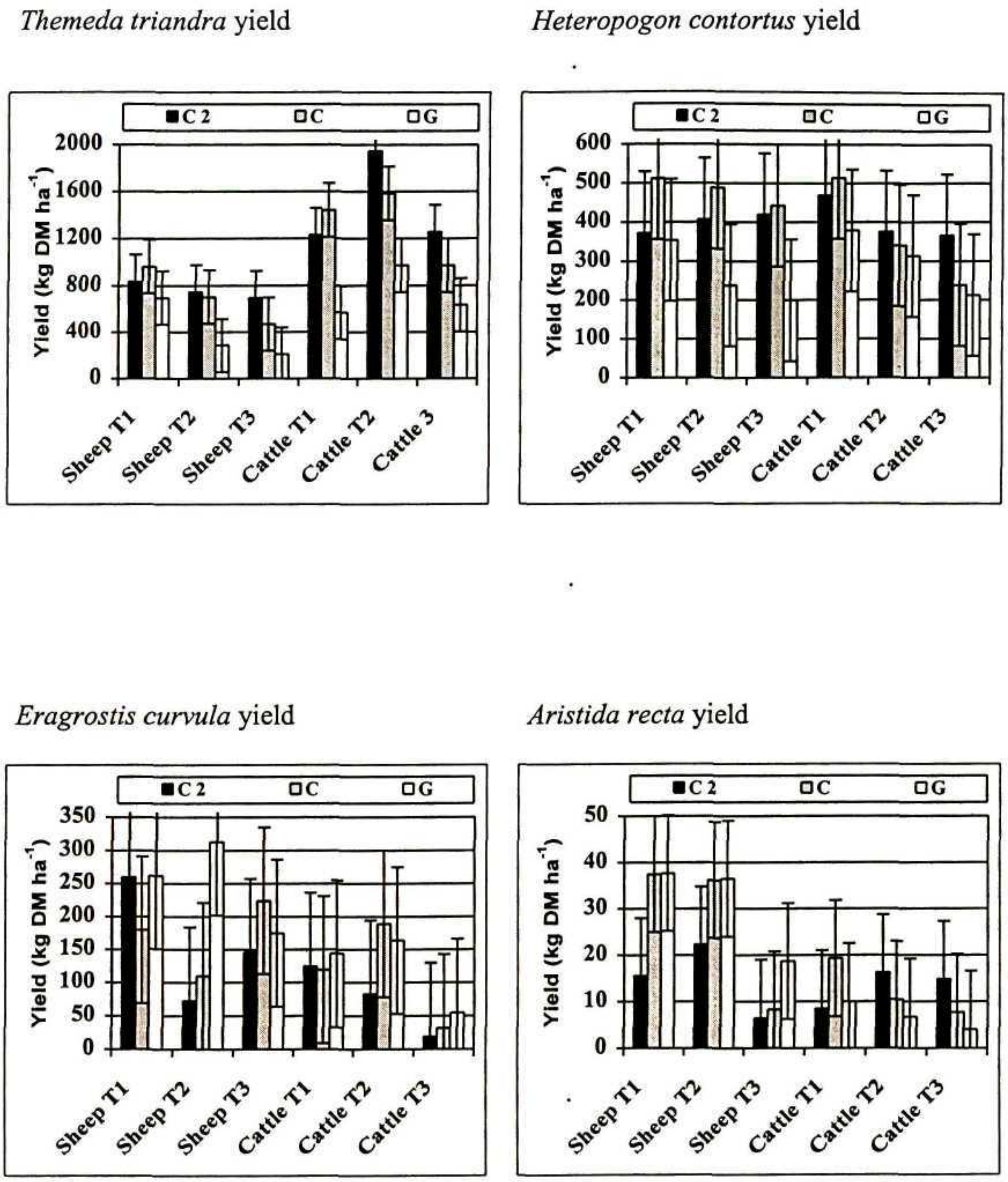
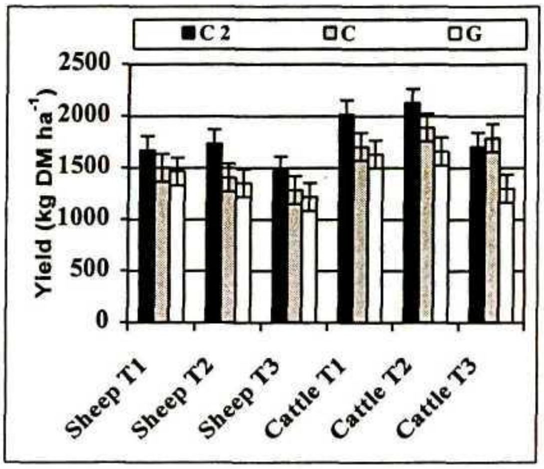
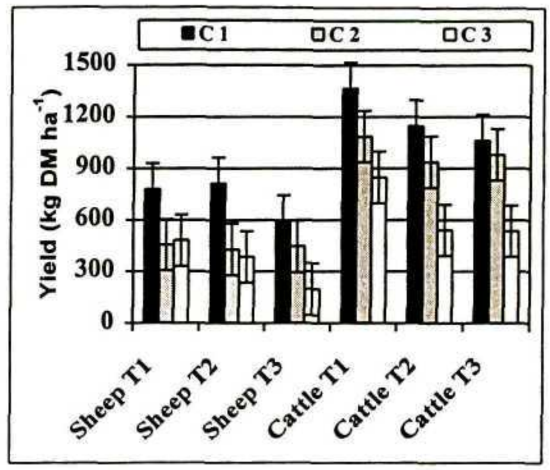


Figure 9.7 Effects of sheep and cattle grazing during the first three seasons on the yield of *Themeda triandra*, *Heteropogon contortus*, *Eragrostis curvula* and *Aristida recta* of the control (C), control 2 (C2 – ungrazed for two years) and grazed plots measured during December 1995. The error bars represent the least significant differences ($P<0.05$)

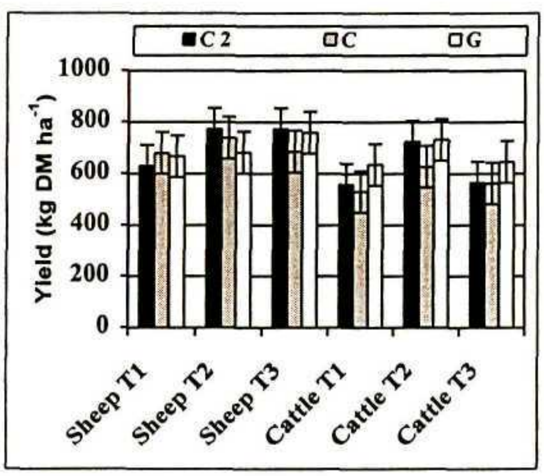
Total yield



Palatable species yield



Intermediate species yield



Unpalatable species yield

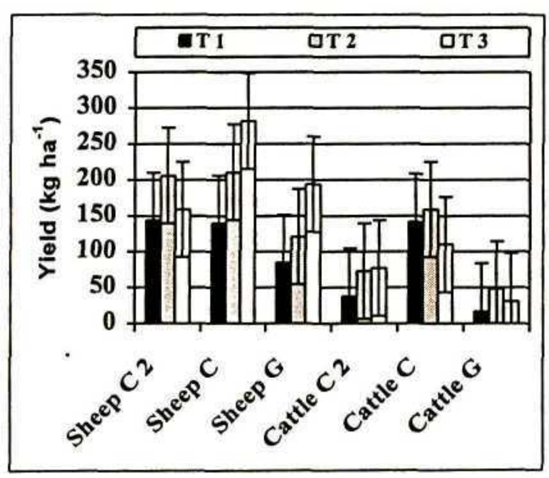


Figure 9.8 Effects of sheep and cattle grazing during the first four seasons on the total yields and the yield of the palatable, intermediate and unpalatable species of the control (C), control 2 (C2 – ungrazed for two years) and grazed plots measured during December 1996. The error bars represent the least significant differences ($P<0.05$)

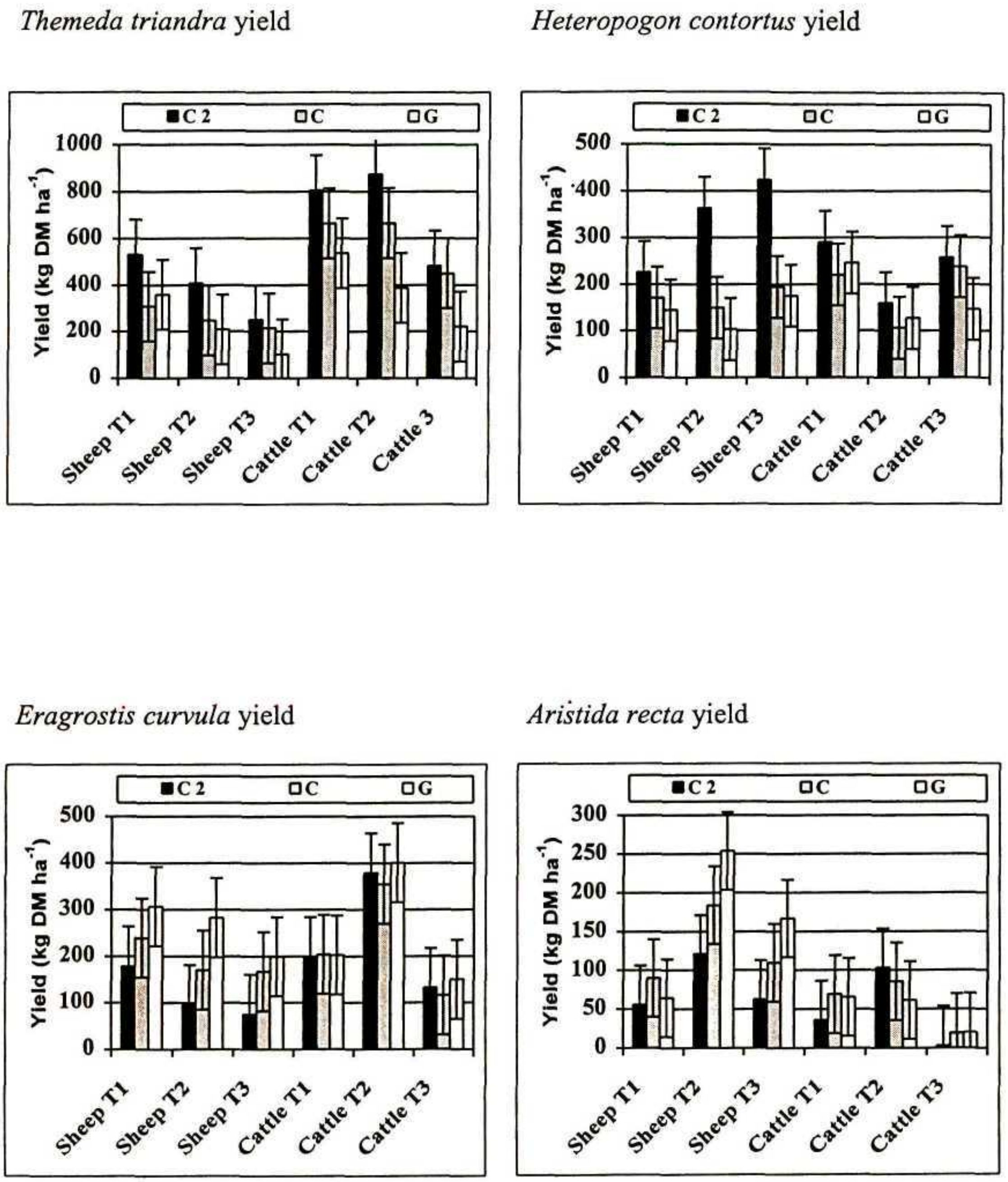


Figure 9.9 Effects of sheep and cattle grazing during the first four seasons on the yield of *Themeda triandra*, *Heteropogon contortus*, *Eragrostis curvula* and *Aristida recta* of the control (C), control 2 (C2 – ungrazed for two years) and grazed plots measured during December 1996. The error bars represent the least significant differences ($P<0.05$)

CHAPTER 10

GENERAL DISCUSSION AND CONCLUSIONS

10.1 Introduction

The research programme reported in this thesis was developed to improve our understanding of the interaction between livestock and veld. In particular, the impact of livestock numbers, livestock type and livestock movement on veld condition was considered important. In addition, the impact of certain of these variables on livestock performance was also considered important. We felt that clarifying our understanding of these interactions would lead to improved grazing management recommendations aimed at developing sustainable livestock production strategies for the sourveld regions of Southern Africa. At the time that this programme was developed, there was a sense of uncertainty regarding the validity of the scientific base on which many grazing management recommendations were founded. Barnes (1992) and O'Reagain & Turner (1992) highlighted this uncertainty.

One of the aspects lacking in many earlier research programmes was a means of quantifying the impact of grazing on veld grass in the short term. Perusal of much of the early literature in South Africa reveals that grazing impact was generally quantified by determining changes in proportional species composition over time. This is a long-term measure and the impact of grazing can only be quantified after an acceptable time period. There is currently no general consensus on the length of time required for accurate quantification of change in this manner, but it is obvious that confidence in the results will increase with the length of trial period. Before the initiation of this research programme, attention was focussed on the measurement of vigour of individual grass species as an objective means of determining residual impact of grazing on grasses in the short term (Barnes 1989a; 1989b; Barnes & Dempsey 1992; Kirkman & Moore 1995; Moore 1989). While not negating the necessity for evaluating the impact of grazing over long time periods, it appeared that using vigour as a short term means of assessing grazing impact would provide valuable insight into grazing impact after relatively few seasons of grazing treatments.

The method chosen for the vigour measurements was the dry-weight-rank method of botanical analysis described in Appendix 1. This method, while commonly used in Australia and several other countries, was relatively unknown in South Africa at the time, with only Barnes *et al.* (1982) and Barnes and Dempsey (1992) reporting on its use. Zacharias (1994) used measurements of grass leaf extension as a means of indexing the relative impact of grazing on vigour. Peddie *et al.* 1995 used etiolated leaf growth in the absence of light as an index of vigour. The advantages of using the dry-weight-rank method included basing the measurements on a quadrat base (easily converted to yield ha^{-1}) using measurements per tuft rather than per unit tuft basal area, rapid measurement of a large scale trial and the ability to include all species in the measurements.

At the time that this programme was initiated, new grazing management recommendations had been formulated locally (for the Mpumalanga Highveld areas) based on research by Barnes (1989a; 1989b) and Barnes & Dempsey (1992). These recommendations, reported in Chapter 1, were based on the incorporation of periodic rotational rest. The frequency of rest depended largely on sheep:cattle ratios, with more frequent rests for higher sheep:cattle ratios. The philosophy behind this rationale was based on the more severe impact that sheep were known to have on veld condition (Barnes 1992; O'Reagain & Turner 1992), and the assumption that allowing veld to rest for extended periods would ameliorate the negative impacts of the sheep grazing. The results of the research carried out by Barnes (1989a; 1989b) and Barnes & Dempsey 1992) suggested that full growing season rests would be successful in this.

The successful adoption and implementation of grazing management recommendations by landowners and land users depends largely on the perceived short-term financial advantage and not on the desire to improve veld condition. Altruism is unfortunately not very common in the agricultural sector (Scholtz 1987). For this reason investigation of the impact of certain management variables on livestock performance was included in the research programme. Any management recommendations emanating from this research programme would thus be based on biological and economic sustainability of veld and livestock production, and should thus be acceptable to livestock producers.

10.2 Evaluation of the objectives

Between the two trials the objectives (restated for reference) were:

1. to quantify the effects of the interaction between stocking rates and time of stocking spring-burnt sourveld on the performance of sheep,
2. to determine the impact of stocking rate and time of stocking on the grazing pattern of sheep by monitoring the changes in herbage mass of each grass species over the grazing season,
3. to determine the impact of stocking rate and time of stocking on veld vigour by quantifying the residual effects on the productivity of the veld as a whole as well as of individual grass species in the year following treatment application,
4. to determine the impact of stocking rate and time of stocking on the proportional species composition of the veld and
5. to establish the impact of different types and frequencies of rests on veld vigour and proportional species composition of sour grassveld grazed by sheep or cattle with various combinations of resting treatments.

10.2.1 Quantification of the effects of the interaction between stocking rates and time of stocking spring-burnt sourveld on the performance of sheep

The sheep stocked as early as possible after burning in spring showed greater rates of mass gain, particularly early in the season, than the sheep stocked three weeks later. Mass gains over the season for the early time of stocking treatment were also greater than those for the late time of stocking. These results concurred with those of Barnes & Dempsey (1992) and Zacharias (1994). However, the sheep used for the late time of stocking treatments were similar in mass to those used in the early time of stocking treatments at the beginning and end of the seasons. This suggests that the advantage of stocking early in terms of livestock performance is not so much increased mass gains, but rather a cost saving early in the spring. If livestock are not placed on the veld early, then some alternative feed source will have to be made available. The quality and resultant livestock performance will be closely related to cost. Preserved feed (hay or silage) may provide satisfactory performance but is relatively expensive. Pasture productivity at this time of year is generally limited for the same reason that veld productivity is limited. Use of poor quality feed (residual foggage from veld or pastures) may be relatively cheap, but performance will definitely be sacrificed. It thus makes sense from a livestock production point of view to stock the veld early. The advantages accrue from avoiding the relatively high cost of reasonable quality alternative feeds, or avoiding poor livestock performance on relatively cheap, poor quality alternatives. There does not appear to be a major advantage in increased mass gain due to stocking early if the livestock to be stocked later are provided with feed of comparable quality for the interim period.

Stocking rate had a clearly observed impact on livestock performance expressed as individual animal performance and as mass gains ha^{-1}. The lightest stocking rate, irrespective of time of stocking, resulted in lower livestock performance than the two intermediate stocking rates. The heaviest stocking rate applied was clearly too heavy and livestock performance dropped as a result. The optimum mass gain ha^{-1} was generally obtained at a stocking rate higher than optimum for individual sheep performance.

The factors influencing livestock performance were found to be extremely complex. The applied treatments had an impact on the quality and quantity of herbage available. Within the available quantity, the treatments also influenced availability of the various species present on the trial site. The interaction between these variables was impossible to quantify objectively, as it seemed that a range of threshold values of the variables under consideration play a role. For example, it seemed (from the data collected as well as visual observation) that whenever the availability of the palatable species dropped to the extent that sheep were forced to eat *Alloteropsis semialata*, then performance dropped accordingly. This was independent of overall quantity and quality of the veld available. The availability of all grass species varied over treatments both in absolute and relative terms, making the isolation of individual species as performance determinants impossible.

Development of a model describing sheep performance in terms of quality (bearing in mind the limitations of the quality data mentioned in Chapter 6) and quantity (bearing mind the lack of sward structure data mentioned in Chapter 6) of available herbage was thus not feasible due to the complexity of the multiple threshold values of the measured variables. The interaction of the quality and quantity variables furhter complicates the situation. O'Reagain (1996b) also acknowledged the complexity of the multi-species veld situation when he stated that an optimum species composition and sward structure for maximum livestock performance could not be specified, as they were dependent on each other, as well as on the season and the animal species involved.

10.2.2 Determination of the impact of stocking rate and time of stocking on the grazing pattern of sheep by monitoring the changes in herbage mass of each grass species over the grazing season

The measurement of grazing patterns by means of quantifying the amounts of herbage available on a species basis throughout the season was very successful. Very clear differences in grazing patterns were observed due to time of stocking and stocking rate. The amount of the palatable grasses available during each season tended to remain constant or decline, depending on grazing pressure. With increasing grazing pressure (early stocking and higher stocking rates), a wider range of species was grazed and grazing was generally less selective. The opposite occurred with lower grazing pressure (lower stocking rates and late time of stocking), where severe selective grazing took place, even within species. Palatability of the grass species encountered on the trial site could be objectively assessed.

10.2.3 Determination of the impact of stocking rate and time of stocking on veld vigour by quantifying the residual effects on the productivity of the veld as a whole as well as of individual grass species in the year following treatment application

All grazing treatments had a severe negative impact on the vigour of the veld. This was manifested by a dramatic decline in the productivity of the palatable grass species and a corresponding general increase in productivity of the unpalatable grasses. The grass species classified as intermediate showed a variable response to the applied treatments. Generally, the intermediate grasses were only grazed once the amount of the palatable grasses had declined to a level of unavailability. In the treatments with higher grazing pressure this occurred relatively early in the season, while in treatments with a low grazing pressure this only occurred later in the season, if at all. The climate in each particular season played a major role. There was an obvious interaction between season and grazing pattern. The season thus influences grazing pressure. It may be appropriate to express grazing pressure in terms of veld productivity and not in terms of area as is the convention. Expression of grazing pressure in terms of area tends to remove the effect of season and climate on veld productivity from assessment of both grazing impact and livestock performance. Expression of grazing pressure in terms of veld productivity or potential productivity would take these variations in to account. Mean herbage production varied between 1701 kg ha^{-1} during the first season and 2959 kg ha^{-1} during the third season. Expressing grazing pressure in terms of area is almost meaningless in the light of this variation.

Time of stocking and stocking rate had a definite impact on the vigour of the veld. The negative impact of grazing on vigour became more pronounced with increasing grazing pressure. However, it appeared that the impact of the time of stocking and stocking rate treatments were secondary to the fact that the veld was grazed. In other words, the fact that veld was grazed was most important in terms of vigour decline. The treatments applied in this study merely influenced the degree of vigour decline. Within the context of this study, none of the treatments could be recommended as ameliorating the negative impact of grazing on vigour.

This concurs with Barnes & Dempsey (1992) who found that deferring grazing in spring did little to ameliorate the negative effects of sheep grazing on veld vigour. Peddie *et al.* (1995) and Lutge *et al.* (1996) also observed a marked decline in vigour during the season following grazing (using a vigour index based on etiolated growth in the absence of light). In the latter two studies the authors found that vigour had been largely restored by the end of a full growing season rest for *Themeda triandra*, but not for *Tristachya leucothrix*.

10.2.4 Determination of the impact of stocking rate and time of stocking on the proportional species composition of the veld

There was a close relation between the impact of the treatments on the vigour of the grass, and the proportional species composition. The proportional composition of the most palatable grass species on the trial site (*Brachiaria serrata*, *Diheteropogon amplectens* and *Monocymbium ceresiiforme*) declined along with a dramatic decline in vigour. This phenomenon certainly broadens our understanding of the cause and effect of grazing impact on species composition and strengthens the perception that, in sourveld, species composition is determined to a certain extent by species vigour. The period of treatment application was somewhat short for determining long-term impacts of the applied treatments on proportional species composition. The measurement of vigour as a predictor of the long-term changes in proportional species composition appears promising.

Barnes & Dempsey (1992) found that time of stocking did not have a marked effect on species composition. In that trial, it was apparent that changes in species composition occurred across all time of stocking treatments and it could be inferred that grazing independently of treatment had an effect on species composition.

There is some empirical evidence that stocking rate has a major influence on species composition (van Niekerk *et al.* 1984; Hardy & Hurt 1989; Morris *et al.* 1992). This was not noted in the present study, probably because the period of study was too short. Van Niekerk *et al.* (1984) stated that effects of stocking rate on species composition tend to occur over a long period (>8 years). O'Reagain & Turner (1992) suggested that species composition may remain constant for a range of stocking rates below a "threshold" stocking rate for any specific plant/climate/soil environment. Once the threshold has been exceeded, species composition is likely to change. This emphasises the importance of short-term measures of grazing impact such as vigour, where the long term effect can be estimated with reasonable confidence.

10.2.5 Establishment of the impact of different types and frequencies of rests on veld vigour and proportional species composition of sour grassveld grazed by sheep or cattle with various combinations of resting treatments

There were major differences between the impact of sheep and the impact of cattle grazing on both the vigour of the grass species and on the proportional species composition. The sheep had a severe negative impact on the vigour of particularly the palatable grass species relative to the impact of the cattle. This negative impact was also seen in the decline in veld condition presented as proportional species composition. Again, there was a close relation between the impact on vigour and the impact on proportional species composition. The decline in proportion of *Themeda triandra* from 21.7 % to 17.7 % in the treatments grazed by sheep contrasted sharply with the increase from 27.3 % to 34.4 % in the treatments grazed by cattle. This is clear evidence of a decline in veld condition under sheep grazing, and an improvement under cattle grazing. A further example was the dramatic increase in proportion of *Aristida recta* from 5.4 % to 23.3 % under sheep grazing, and the moderate change from 5 % to 5.6 % under cattle grazing. Visually, the differences between the sheep and cattle treatments were forceful. The difference in impact of sheep and cattle grazing on vigour was evident as a decline in total vigour (all species grouped together), a decline in vigour of palatable species, a marginal increase in vigour of intermediate species and a substantial increase in vigour of the unpalatable species under sheep grazing. The impact of grazing on total vigour is probably related to species composition in that if the veld comprised predominantly of unpalatable species, then productivity of the veld as a whole may increase as a result of grazing. The difference in impact of sheep and cattle grazing was also clearly seen on the two species mentioned above. Sheep grazing had a severe negative impact on vigour of *Themeda triandra* relative to cattle grazing. In contrast, grazing by sheep increased the vigour of the undesirable *Aristida recta* relative to cattle grazing.

The impact of the three resting treatments applied seemed to be smaller than the livestock type treatment. The major factor influencing veld vigour and condition was thus livestock type, and not resting type or frequency. Species composition tended to improve slightly with higher resting frequency. A rest treatment under sheep grazing is, however, not as beneficial as a rest treatment under cattle grazing. The grazing treatment between rests appears to have a greater influence on both species composition and vigour than the rest between grazing events.

The marked changes in species composition between the sheep and cattle grazed treatments are not entirely consistent with other South African studies. Hardy (1994) reported that species composition under a range of sheep:cattle ratios was relatively stable. Malherbe (1971) reported similar results for a range of sheep:cattle ratios.

The contrast between the marked changes in species composition noted in Trial 2 and the relative stability noted in Trial 1 may be related to the different past management practices on the two sites, differences in initial composition of the veld, the difference in soil types and the different stocking rates applied relative to the veld productivity. The veld used for Trial 1 (Athole) initially had a relatively low proportion of unpalatable species compared to the veld used for Trial 2 (Nooitgedacht). The veld used for Trial 2 may have been closer to a "threshold" composition (O'Reagain & Turner 1992), which could mean accelerated change in species composition beyond the threshold. The effect of competition between species was not directly studied in the present research programme. Morris & Tainton (1993) examined the effects of defoliation and competition on the vigour of *Themeda triandra and Aristida junciformis* and found that *Aristida junciformis* was more sensitive to defoliation than *Themeda triandra*. Competition appeared to suppress vigour of *Themeda triandra* to a greater extent than *Aristida junciformis*. This phenomenon is in broad agreement with the results of the current trial. *Aristida recta* in this case was leniently defoliated by cattle but not defoliated at all by sheep in Trial 2. This could partially explain the major differences in vigour of *Themeda triandra* and *Aristida recta* between the sheep and cattle treatments. These effects on vigour would then affect the species composition as recorded. The more favourable species composition of the veld on Trial 1 (Athole), implied less competition for the palatable species, which may partially explain the more stable species composition encountered.

The close relations between the measurement of vigour and proportional species composition is again promising in that it appears that vigour could be used as a short term measure of the expected change in species composition.

10.3 General discussion

The results obtained in this study are important in terms of enhancing our understanding of the interaction between livestock and veld. In particular, the quantification of the effects of stocking rate (in terms of the familiar Jones & Sandland (1974) model) is important for grazing management recommendations. The complexity of the factors influencing livestock performance has been highlighted. In particular, the role of individual veld grass species in determining livestock performance has been identified. Progress towards developing a predictive model describing livestock performance in terms of the data collected in the study was disappointing. However, it is believed that the current level of understanding the complex interactions of the factors affecting livestock performance has been improved. In particular, it appears that more detailed quality analyses of veld grasses are necessary. Also, the role of vegetation structure (O'Reagain 1996b) appears to be important. The quantification of the effects of stocking rate on sheep performance in terms of the Jones & Sandland (1974) model has important implications for veld management recommendations, even if a predictive model could not be developed. The most important definitive results obtained in this study relate to the impact of grazing on veld vigour and proportional species composition. The impact of grazing on veld grasses has been quantified in terms of veld grass productivity, which can be directly related to livestock production, as well as species composition. The overall negative impact of grazing on vigour found in this study concurs with studies by Barnes & Dempsey (1992) and Zacharias (1994).

Evaluation of veld management recommendations proposed before the initiation of this study reveals certain shortcomings exposed by this study. The perception that rest is an almost overriding beneficial treatment for veld has been shown to be not entirely true. While resting had a positive impact on vigour and species composition, the grazing treatment applied between rests appears to be more important than the rest itself (e.g. interaction between rest and livestock type). This was strongly evident when comparing the impact of sheep and cattle grazing on veld. The difference between the impact of sheep and cattle grazing on veld vigour and condition is probably greater than previously realised. None of the treatments applied were able to rectify the negative impact of sheep grazing.

The application of rests in veld management strategies as outlined in Chapter 1 appears to be valid, particularly from a fodder-flow perspective. However, the perception at that time that veld grazed by sheep with regular application of rests will be maintained in a condition similar to veld grazed by cattle is false. This conclusion is in line with findings by O'Reagain & Turner (1992) who found that sheep definitely have a greater potential to damage veld condition than cattle.

While a comparison between continuous and rotational grazing was not one of the objectives of this study, it is interesting to note that the impact of continuous grazing in Trial 1 and rotational grazing in Trial 2 had similar effects on veld vigour.

This study led to an overall improvement in understanding the interaction between veld and the grazing animal, particularly with regard to the impact of grazing on veld vigour and species composition. Further knowledge gaps not yet addressed include veld grass population dynamics, including tuft longevity and re-establishment by seeds under sheep and cattle grazing conditions. The role of competition between defoliated species and undefoliated species is not yet fully understood.

10.4 Resultant grazing management recommendations

The effects of stocking rate and time of stocking on livestock performance indicate that there is scope for manipulating livestock performance by controlling the amount of herbage available. The interaction between climate and stocking rate complicates the practical application of this principle. It seems that by using a flexible procedure (such as the indicator paddock approach outlined in Chapter1) within any particular grazing season, it may be possible to successfully improve livestock performance. It is impossible based on the current data available to set out recipes for success in this approach, because each situation differs and each farm differs in terms of species composition and productivity. Each season will also differ. The main criteria determining the success or failure of this approach will probably be the judgement of the manager. Each manager will have to understand the principle of providing enough but not too much feed consistently throughout the season for the livestock, and then apply the indicator paddock approach in a manner to achieve this. Through experience and by spending time observing the livestock grazing patterns, it should be possible to achieve success.

Experience in the development of farming systems based on various resource scenarios (Anon 1997) has shown that the provision of an appropriate fodder-flow is essential in maintaining or raising the profitability of livestock production enterprises in the sourveld regions. This includes provision of adequate quality and quantity at times to match the quality and quantity required by the livestock. Evaluation of feed resources is a necessary first step in planning any livestock enterprise. Matching the livestock production system to the feed resource base is preferable to attempting to manipulate the feed sources to the livestock production system. In the sourveld regions veld is generally used for extensive livestock production during summer. For the winter period, the two common feed resource scenarios are, firstly, sufficient arable land to provide sufficient crop residues for wintering livestock, and secondly, insufficient or no crop residues for wintering purposes.

Where sufficient veld is available for wintering purposes, then resting for the purpose of providing feed for winter use is not a priority. However, rested veld can still be successfully incorporated in the fodder-flow for the periods before the crop residues are available (May, June and sometimes part of July), and for certain classes of livestock that don't need high quality feed (e.g. dry animals). This has been successfully demonstrated for both sheep and cattle in the livestock production system development programme at Athole (Anon 1997).

Where insufficient alternative feed is available for winter use, then it makes economic sense to rest at least enough veld for wintering livestock. The production system should then be designed to fit the fodder-flow, with spring lambing and calving seasons to make full use of the high quality feed available in summer, and the lower quality winter veld used for wintering pregnant female animals. This approach has also been successfully demonstrated in the Athole system development programme.

The results of this study show some advantage of resting veld for increased vigour and improved species composition under both sheep and cattle grazing. This, together with the provision of cheap winter-feed, make resting an important part of grazing management. Rests can be applied in a number of ways. The two- and three-block strategies mentioned in Chapter 1 are appropriate means of incorporating rest in a grazing management strategy. The five-cell system (Murray 1995) may be even more appropriate. The benefits of a two year rest were shown in terms of increased vigour in trial 2. The five-cell system formally incorporates a two year rest once in every five-year cycle. While the combination of sheep and cattle were not investigated in this study, it would seem from previous work (Hardy 1994) that sheep and cattle should be grazed in combination, even if only to lower the sheep numbers on the veld.

10.5 Conclusions

Livestock performance can be manipulated by stocking rates, and to a lesser extent, time of stocking in spring. The interaction between climate and stocking rate as a major factor determining feed quantity and quality is an important influence on livestock performance.

Grazing has a severe negative impact on veld grass vigour. Grasses that are grazed more severely are affected more than grasses that are grazed less severely. Unpalatable grasses that are seldom, if ever, grazed generally increase in vigour. Manipulation of stocking rate and time of stocking played a relatively minor role in terms of impact on veld vigour and condition over the period of the trials. The fact that veld is grazed seems to be the major factor determining vigour and condition. Sheep have a far more detrimental impact on veld vigour and species composition than cattle. Veld condition in this study improved under cattle grazing and deteriorated under sheep grazing. The impact of rest on veld vigour and condition depends largely on the grazing treatment between rests. Periodic rest alone can thus not be considered as a therapeutic treatment for badly managed veld.

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APPENDIX 1

MEASUREMENT OF VELD VIGOUR, HERBAGE ACCUMULATION AND DISAPPEARANCE, AND GRAZING PATTERNS

Measurement of species composition is fundamental to veld research and monitoring. Measures of species composition commonly used include proportional composition, density, frequency, cover, basal cover and dry weight. Of these, species dry weight contribution to total dry weight production can be considered a good indicator of species importance with respect to animal production.

In this study, measurement of veld vigour (on a species basis), herbage accumulation and disappearance under grazing and grazing patterns were fundamental in answering certain questions.

Vigour

It is well established that the deterioration of sourveld as a grazing resource is primarily due to the loss of vigour and eventual death of the preferred grass species (Tainton 1981a). Disappearance of the preferred species is usually accompanied by an increase in the proportion of undesirable species (Tainton 1981a). This process can be attributed to the inability of the preferred grass species to withstand intensive and long continued grazing (Barnes 1992). In addition, the debilitation is usually augmented by competition from undefoliated or lightly defoliated unpreferred species (Barnes & Dempsey 1992).

Quantifying vigour is thus vitally important in understanding the reaction of veld to differential grazing management. Although the term vigour is often used, no precise definition of grass vigour has been found. Tainton (1981b) related vigour to the ability of a plant to produce reasonable quantities of viable seed and its ability to supply nutrients to both the existing tillers and of new tillers if the plant is to survive from one season to the next. Barnes (1989a) and Barnes & Dempsey (1992) related vigour to the productivity of grass plants in the season following defoliation measured against the productivity of comparable undefoliated plants. For the purpose of this discussion vigour of grass has been defined as the ability of a grass plant to regrow after defoliation.

While it is difficult to measure the ability of a plant to grow, two measures have commonly been used as vigour indices of grasses subjected to differential defoliation treatments. Firstly, measurement of the mass of roots and stem bases and the non-structural carbohydrate (NSC) content of these (e.g. Weinmann 1948; 1961) can be carried out as an indicator of the ability of a grass plant to regrow. Secondly, the rate or amount of herbage growth in the season following that in which differential treatments were applied (e.g. Barnes 1960; 1989a; Moore 1989; Barnes & Dempsey 1992) can be carried out. This can be compared to the growth of undefoliated control plants as an actual measure of the residual effect of the defoliation treatment on grass vigour.

The determination of root mass is destructive, difficult and time consuming and measurements of root mass tend to have a high coefficient of variation (Troughton 1981).

The relation between NSC content of the storage organs and grass regrowth is tenuous. While results from some studies have shown this relation to have a high correlation (e.g. Barnes 1960), in other studies this relation is unsubstantiated (e.g. Richards & Caldwell 1985). Possible reasons for this lack of correlation are that NSC reserves as determined by traditional procedures do not adequately represent the reserves available for regrowth, that the contribution of concurrent photosynthesis to regrowth is large relative to that of reserve NSC and that meristematic restrictions limit regrowth (Richards & Caldwell 1985). Results from local research indicate that patterns of change in the NSC contents of the roots and stems of some local sourveld grasses subjected to differential defoliation frequencies and intensities are inconsistent (Moore 1989).

Barnes (1989a; 1989b) investigated the effects of differential grazing schedules on the vigour of three species, *Themeda triandra*, *Heteropogon contortus* and *Trachypogon spicatus*, by measuring herbage regrowth in the season following grazing. The regrowth of the grazed treatments was compared to that of an ungrazed control and it was found that grazing severely influenced grass vigour. Two methods were used to measure the grass regrowth, and it was noticed that there were marked discrepancies between the regrowth expressed as yield per unit tuft basal area and regrowth measured as yield per quadrat.

In a follow up study the effects of various defoliation treatments on grass vigour was investigated under strict control in a cutting trial (Kirkman & Moore 1995). In addition to the main objectives of the trial, the discrepancies between the different methods of measuring grass regrowth during the season following grazing (Barnes 1989b) were investigated to facilitate accurate quantification of vigour. As this discrepancy indicated differences between yield and yield expressed per unit tuft basal area, the aim was to compare these two measures. Also, the yield of *Themeda triandra* was measured by harvesting quadrats.

Discrepancies between yield expressed per tuft and yield expressed per unit tuft basal area during the season following treatment were found. The results expressed as yield per tuft showed severe effects of defoliation on vigour. These effects were strongly related to the severity of the defoliation treatments. The results expressed as yield per unit tuft basal area showed no significant effects on vigour. In addition, the trends did not coincide with the severity of the defoliation treatments. These discrepancies between the productivity measures expressed as yield per tuft as compared with yields per unit tuft basal area were similar to those found by Barnes (1989b), and raised crucial questions regarding the criteria for the determination of vigour by measuring regrowth productivity.

The effects of defoliation on grass tiller initiation and development are well documented (e.g. Tainton 1981c). It seems logical that under certain circumstances a change in vigour of some grass species may be reflected by a change in tuft size. This may be caused by a change in tiller numbers as well as growth of individual tillers, rather than just the amount of growth per tiller or per unit tuft basal area. The species yield per tuft or per unit land area may thus change, but differences in yield per unit tuft basal area may not reflect this. Kirkman & Moore (1995) investigated the effect of different defoliation treatments on tuft basal area during the season following treatment and found significant differences in tuft basal areas between treatments. These differences showed a relation to treatment severity and this suggested that defoliation in this study had an effect on tuft basal area.

It seems logical therefore that the effects of differential defoliation treatments on the vigour of grass should be expressed as mean yield per tuft as opposed to mean yield per unit tuft basal area. It should be noted that measures based on tiller or leaf length are logically equivalent to measures expressed per unit tuft area.

The use of quadrats as a means of selecting tufts for yield determination has certain benefits, particularly when several species are under investigation. It facilitates the expression of species yield per unit land area, which gives extra significance to the results by relating species vigour to grazing management (e.g. grazing capacity and animal performance). In the study by Kirkman & Moore (1995), yield of *Themeda triandra* was also determined using quadrats. The vigour index obtained showed similar trends to that obtained from the measurement of yield per tuft, although the scale of the index was somewhat lower.

It must be noted that species yield determined by harvesting quadrats and separating the herbage by species as done in this study is subject to error arising from the variability of proportional species composition on a quadrat scale (Barnes 1989b). One way of eliminating this error would be to determine the quadrat yields, and to establish the proportional composition of the herbage mass per quadrat on a species basis.

It was thus decided that measures of grass productivity (or vigour) be expressed as species yield per unit land area to increase the relevance of vigour measurements. This can be done by harvesting each species within a quadrat separately to determine species yield as a proportion of total yield. Non-destructive, less laborious and time consuming are estimation techniques such as the dry-weight-rank (DWR) method (t'Mannetje & Haydock 1963).

Some 30 years ago t'Mannetje & Haydock (1963) proposed the use of the dry-weight-rank method for the non-destructive determination of the percentage mass of the herbage of each species present in mixed-species pastures. Jones & Hargreaves (1979) suggested modifications of the method leading to increased accuracy. The modified technique has been tested and found to be suitable in Zimbabwe (Kelly & McNeill 1980) and in the eastern Transvaal Highveld (Barnes *et al.* 1982), who suggested further modifications to increase accuracy. Further afield, the DWR technique has been evaluated and found suitable for measuring species dry weight by Gillen & Smith (1986), Friedel *et al.* (1988) and Mazaika & Krausman (1991) under a wide range of conditions.

DWR method

The method is outlined as follows (adapted from Barnes *et al.* 1982):

1) Quadrats are placed in a manner representative of the area to be surveyed. The quadrat size is important and should be selected to include at least three species in most of the quadrats, and small enough to enable the operator to allocate ranks quickly and accurately. The number of quadrats required is linked to the level of accuracy desired.

2) For each quadrat the operator estimates which species comprise the greatest, second greatest and third greatest amounts of herbage within the quadrat on a dry-weight basis.

3) Ranks 1, 2 & 3 are allocated to these species respectively. If only one species is present in a quadrat, all three ranks are allocated to this species. If only two species are present, ranks 1 & 2 are allocated to the clearly dominant species and rank 3 to the subsidiary species, or if the dominant species is judged to be only slightly more than the subsidiary species, then rank 1 is allocated to the dominant species and 2 & 3 to

subsidiary species. Also, if a species comprises more than about 85 % of a quadrat, it is allocated both the first and second ranks. This procedure is known as cumulative ranking and is described by Jones & Hargreaves (1979). If this cumulative ranking procedure has to be used too frequently, the DWR technique may not be suitable for the specific site.

4) If species appear to be equal in dry-weight, then the relevant rank can be allocated equally to the species concerned (a modification termed "shared ranks" suggested by Barnes *et al.* 1982).

5) Minor species or non-grasses can be grouped together, e.g. "other grasses", "forbs", "sedges" or "weeds".

6) In the simplest form of the method, as reported by t'Mannetje & Haydock (1963), the data obtained in this manner are tabulated to give the proportion of quadrats in which each species is ranked first, second or third. Where a rank is allocated equally to two or more species in a quadrat, the quadrat value of unity for the rank concerned is divided by the number of species to which the same rank is allocated before summation of the numbers of quadrats by ranks and species. The proportionate values for ranks 1, 2 & 3 are respectively multiplied by the empirically derived "percentage" multipliers 70.19, 21.68 & 8.73 (t'Mannetje & Haydock 1963). The products for each rank are added to give percentage dry matter for each species.

7) Alternatively, or where the ranks are not all filled in one or more quadrats, the total number of quadrats in which a species is ranked first, second or third respectively are multiplied by the percentage multipliers converted to their ratios ("proportional" multipliers), i.e. 8.04, 2.41 & 1.00. The products are then added to give a score for each species. These scores, when converted to a percentage of the total of the scores for all species give the percentage composition by mass. This can then be expressed as proportional composition by mass of each species if the total yield of the area is known.

Jones & Hargreaves (1979), Kelly & McNeill (1980) and Barnes *et al.* (1982) showed that the precision of the DWR estimate is increased by weighting the ranks for each quadrat on the basis of the dry matter yield for each quadrat before summation by ranks. This requires a suitable non-destructive method of estimating the total yield of each quadrat used in the DWR analysis.

Several non-destructive techniques for the estimation of pasture yield have been proposed, of which the disc meter is probably the most well known in South Africa. The disc meter may not be accurate enough for use on veld that has been grazed selectively (i.e. a mosaic of tall and short tufts) or short, particularly where this occurs on stony or uneven ground. Alternative techniques include the comparative yield method (Haydock & Shaw 1975) and the double sampling method (e.g. Reich *et al.* 1993).

The double sampling yield estimation technique appears to be the most suitable technique to provide a rapid means of estimating the yield of each quadrat used in the dry-weight-rank analysis. This is used to provide the weighting necessary for increased precision. This is done quite simply by estimating the yield of each quadrat, using the double sampling method, while simultaneously allocating ranks to each species in the quadrat using the DWR technique.

Double sampling technique

In the double sampling technique the yields of grass in a series of quadrats are visually estimated on a suitable scale. By harvesting a proportion of the quadrats a regression is then established between the estimates and the corresponding actual mass of the material in the harvested quadrats. This technique is essentially similar to the disc meter method, except that the operators' visual estimate of the yield of each quadrat is substituted for the disc reading.

It has been found that, after an initial training period, operators are usually able to estimate so as to obtain linear relations between estimates and actual yields. In some cases, especially in selectively grazed veld, a curvilinear, usually exponential relation is obtained. The regression coefficients obtained locally are commonly between 0.87

and 0.93. It is important to note that calibration is specific to each operator, and that is necessary to re calibrate on each sampling occasion.

These techniques were thus used successfully in combination for quantifying seasonal grazing patterns on veld, the differences in grazing patterns between treatments and animal types, and for measuring the residual effects of grazing treatments on species vigour. This was done by measuring the individual species production in the season following treatment as compared to that of an ungrazed control.

Griffin & Bastin (1988) have developed computer programs for processing such data using hand held computers, and the BOTANAL package was developed for monitoring pasture yield and composition (Waite 1994).

Suitable hand held computers were not available, and neither of these packages was available locally at the time this study was initiated. A spreadsheet based computer program for IBM compatible computers was developed to process the DWR and double sampling data.

APPENDIX 2

LIST OF GRASS SPECIES WITH ABBREVIATIONS AS USED IN CERTAIN TABLES

Species	Abbreviation
Alloteropsis semialata	Allsem
Andropogon appendiculatus	Andapp
Aristida recta	Arirec
Aristida spp. *	Arispp
Brachiaria brizantha	Brabri
Brachiaria serrata	Braser
Brachiaria sp. **	Braspp
Ctenium concinnum	Ctecon
Cymbopogon excavatus	Cymexc
Cynodon spp. *	Cynspp
Digitaria flaccida	Digfla
Digitaria monodactyla	Digmon
Digitaria tricholaenoides	Digtri
Diheteropogon amplectens	Dihamp
Elionurus muticus	Elimut
Eragrostis capensis	Eracap
Eragrostis curvula	Eracur
Eragrostis plana	Erapla
Eragrostis racemosa	Erarac
Eragrostis spp. *	Eraspp
Eulalia villosa	Eulvil
Harpochloa falx	Harfal
Heteropogon contortus	Hetcon
Hyparrhenia hirta	Hyphir
Koeleria capensis	Koecap
Loudetia simplex	Lousim
Melinis nerviglumis	Melner
Microchloa caffra	Miccaf
Monocymbium ceresiiforme	Moncer
Panicum ecklonii	Paneck
Panicum natalense	Pannat
Rendlia altera	Renalt
Setaria nigrirostris	Setnig
Setaria sphacelata	Setsph
Stiburus conrathii	Sticon
Themeda triandra	Thetri
Trachypogon spicatus	Traspi
Tristachya leucothrix	Trileu
Non-grasses	NG

* More than one *Cynodon*, *Eragrostis* and *Aristida* species occurred that were similar and were consequently grouped together. The *Aristida* species grouped together were additional to the *Aristida recta* tabled above. The *Eragrostis* species grouped together were additional to the individually identified *Eragrostis* species tabled above.
** An unidentifiable *Brachiaria* species was labelled as *Brachiaria* sp.